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February 2010

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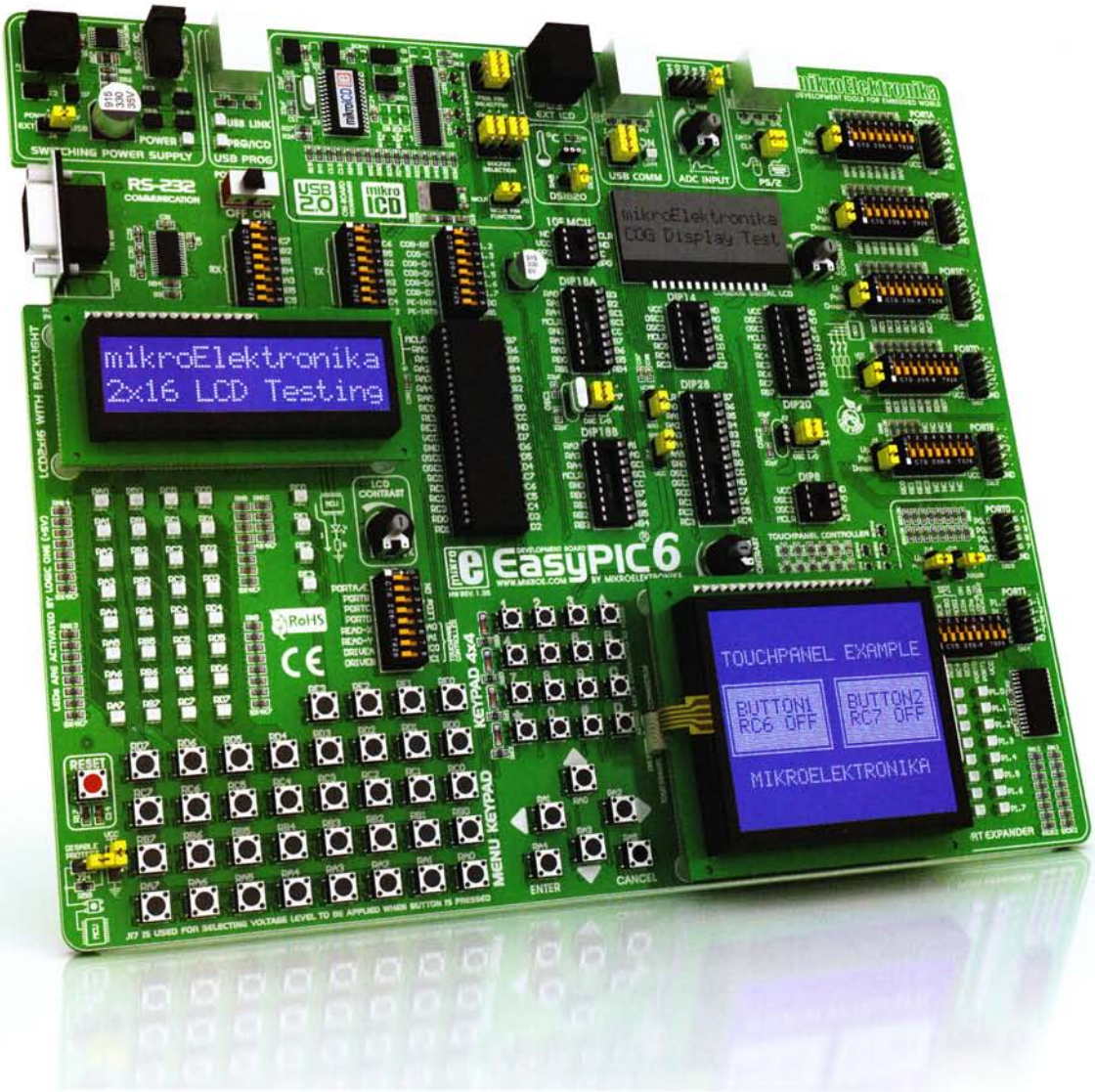
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Power — not brawn

'Power' was set as the theme of the month and powerful it will be. For many electronics enthusiasts, designing power supplies is a necessary evil. And when the power level lies in the ampère range instead of the milliampère range, quite a few designers find themselves in unknown territory. However, this can be remedied by new highly integrated chips, ready-made driver modules, and clever reference designs. In addition, many tools are available on the Web, and most of them are free. In this the February 2010 issue of Elektor we provide get-you-going information on the subject (or keep-you-going?) in two articles, *Stable Starting Points* (page 20) and *Torture Rack* (page 23). To which I should hasten to add *Tailored Cooling* (page 14) because sadly some of the power you've paid for goes to waste as heat and we should find ways to deal with that!
Also on power wastage, while modern lamp technology claims to reduce electrical power consumption besides making us sleep better and feel less troubled with eco concerns, it also prompts a critical look at PFC (power factor correction). A non issue with the traditional incandescent light bulbs rapidly being phased out, PFC now looks like area where technology is not, or not yet, making a contribution to power economies — in short, a lower electricity bill. We did some research on off the shelf lamps claimed as 'all the latest' and you can read the results on page 60. *Femto OS* on page 38 proves that a lot of computing power can be packed in just a few kilobytes, just as we did in the old days when RAM was scarce & costly and programming required thinking instead of just pizzas, beer and broadband DSL. It should also stimulate many multitasking OS writers and suppliers to have a more than critical look at the size of their final product as it's often gargantuan compared to the application itself. WLAN routers and WiFi devices are now firmly established in the 2.4 GHz ISM band, all clamouring for bandwidth to operate properly. Our *2.4 GHz Bandalyser* (page 54) will not just tell you just how busy the band is in your area, but also the where/what/who about the main interference sources your router should avoid by clever channel hopping now and then.

Jan Buiting
Editor

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This intelligent battery checker will determine the state of cells so that an optimal selection can be made from them to form a pack. It is essential to measure not only the capacity of the cells, but also their internal resistance.

38 Femto OS

Here's a minuscule multitasking operating system that's currently ported to 44 of Atmel's AVR microcontrollers. It is open source and licensed under GPLv3. Femto OS is different! For one, it's is extremely economical with RAM and flash memory.



54 The 2.4 GHz Bandalyser

With this handy portable scanner, you can quickly and easily see which WiFi and WLAN frequencies are being used in your area and which channels you should avoid for your own wireless network links.

60 Blinded by the Light?



The latest lamp technologies are claimed to save huge amounts of power but has their power factor correction (PFC) been overlooked or is it a simple matter of poor standards and sluggish industry regulation again? We investigate.

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Elektor International Media provides a multimedia and interactive platform for everyone interested in electronics. From professionals passionate about their work to enthusiasts with professional ambitions. From beginner to diehard, from student to lecturer. Information, education, inspiration and entertainment. Analogue and digital; practical and theoretical; software and hardware.



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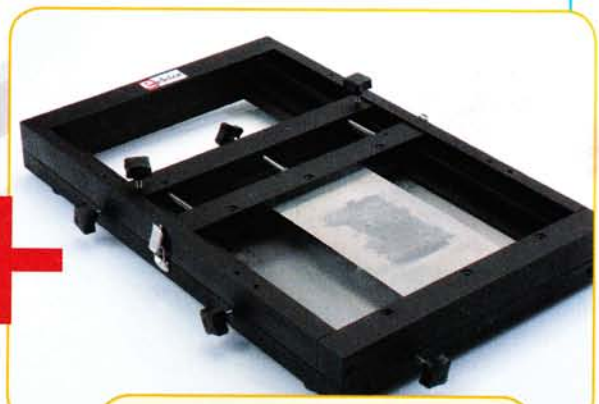
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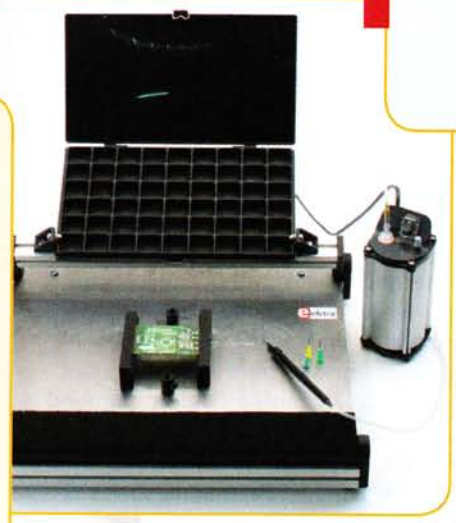
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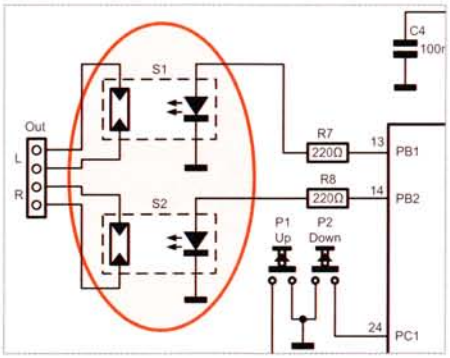
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AVR, dB and LDR collide at D/A Junction

Elektor November 2009, page 43, ref. 080654

Dear Sir — I hesitate to imply any sort of criticism of your excellent organ, but I must comment on the recent article "AVR, dB and LDR Collide" by Daniel Rodrigues. Daniel is very critical of a design using a light dependent resistor (LDR) in a digitally controlled volume control. The basis of his criticism is the resistive range of an LDR was only 50 to 2000 ohm. In fact there are plenty of LDRs available with dark resistance of up to 25 megohm which is altogether a different kettle of fish. In this sort of application an LDR could be used very effectively as one leg of a potential divider, to replace a conventional potentiomer in a low-level part of the circuit. In some configurations this device can be made to approximate a log-law potentiometer for audio applications. This not only provides a solid-state alternative to a potentiometer, but also makes it easy to create multi-ganged devices controlled by a single voltage source.
It is easy to make a resistive optocoupler by gluing an LED to an LDR and covering the assembly with heat shrink sleeving. Alternatively these devices are available ready made, such as the Silonex NSL32SR3.
On a note of thanks, I always enjoy reading Elektor from cover to cover, and I particularly like the Retronics column.

Paul Lister

Daniel Rodrigues replies: actually, the component Mr. Lister refers to was tested. I did not mention the component because it's not RoHS compliant (which is not stated in the datasheet though!). It's also slow (taking 10 sec to achieve 25 MΩ), distorts the audio signal and it's not RoHS compliant, containing high amounts of cadmium. So, it's becoming increasingly difficult to find LDRs with a larger resistance range. It may also be worth noting that the circuit as discussed in the article is based on the LDR being inserted in the (low-power) loudspeaker line.

Circuit suggestions for T-Reg (2)

Mailbox, December 2009, page 8.

Dear Editor — I read the letter in December 2009 Elektor from Alexander Voigt with interest. I can add a little to your discussion on failures of valves; I worked on the rebuild of the Colossus computer at Bletchley Park for several years. That machine uses 2,500 valves and we had to replace valves now and then. There are at least two ways that valves can be damaged. The first is called cathode stripping: this is where the anode voltage is applied before the cathode is at working temperature. Because the vacuum in the tube is not perfect, ions can form and fall back onto the cathode and because they are heavy, they knock the coating off the cathode.
The second is called cathode poisoning: this is where the cathode is at working temperature but there is no (or little) anode voltage to attract electrons out of the cathode. A cloud of ions forms around the cathode and this eventually leads to contamination of the material which forms the cathode. Thermionic valves in early computers suffered this fate because logic gates are either on or off. If off, then cathode poisoning is possible as no anode current is flowing, often for long periods.
I hope this helps. An excellent magazine.

Charles Coultas

Thanks for that Charles and keep up the good work at Bletchley Park.

Suggestions for Retronics

Hi Jan — thanks for a great magazine. You have appealed for new subjects for your 'Retronics' series of articles. Here goes:
1) Magnetic Amplifiers and indeed, the whole suite of saturable reactors and oddball miscellaneous transductors. Fascinating devices.
2) The Amplidyne, Metadyne and Magnicon rotary amplifiers. OK, they may originate more from the heavy-power end of the electric-device spectrum but they are especially interesting for shear ingenuity and the capability of controlling massive amounts of power with such a small magnitude of control current.
3) We take cheap, mass-produced consumer goods for granted but the fact that this is possible rides solely upon the back of advanced sensor/transducer technology. Could you delve into the early days of these devices. Just to kick this one off, have a look at the Petoscope. I think you will be intrigued.
4) I would particularly like to see something on the "might-have-been" devices that never quite got out of the lab. For example., ultra-miniature vacuum-tube 'chips' designed using silicon integrated circuit technology, cold-cathode substrate materials (no, I'm not talking about orthodox cold-cathode gas-filled tubes but the elimination of the heater entirely), revolutionary display technologies, even most recently, the abandoned new-concept electron-emission method behind Canon/Toshiba's flat-screen alternative.
I trust this keeps you busy!

Andre Rousseau

The Petoscope and the 'might-have-beens' in particular should make excellent reading in Retronics, which I started writing and editing in December 2004 and is currently in its 53rd instalment mostly thanks to the encouragement, hints, equipments, oddball devices and enthusiastic contributions I got from you, the Elektor readership. The same for the subjects Andre has kindly suggested — if anyone can come up with a 700-word article on the items mentioned, or simply his/her favourite vintage equipment or electronics device, do not hesitate to contact me.

Jan Buiting, Editor.

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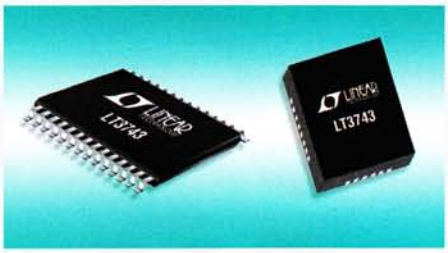
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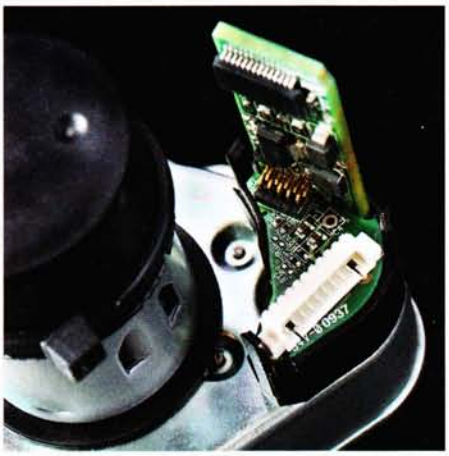
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The LT3743EUFD is available in a 28-pin 4mm x 5mm QFN package, whereas the LT3743EFE is available in a thermally enhanced TSSOP-28. Extended temperature versions, or 'I' grades, namely the LT3743IUFD and LT3743IFE are also available. All versions are available from stock.

www.linear.com (090832-VI)

ByteSnap showcases electronics design projects at Southern Electronics 2010



For the first time at Southern Electronics in Farnborough from 10 – 11 February 2010 on stand D12, ByteSnap Design will be demonstrating its work for Rotalink, a designer and manufacturer of miniature motors, transmission and controls. The companies will be highlighting a new product which measures the precise position of a gearbox running at up to 500 rpm and the number of turns made. The new product will be of potential interest to a wide range of applications including valves, lighting effects, antenna positioning, seat adjusters, curtain openers and instrumentation.
ByteSnap Design will also be showcasing its bespoke embedded electronics design, embedded firmware and board design services. The company will also highlight work it has undertaken for its clients that has speeded up product time to market and created innovative, robust and high quality electronics and software products.
Visitors to the stand will be able to see other products that ByteSnap Design has successfully helped to bring to market, including working prototypes of a GSM based M2M device, the Zigbee and Bluetooth based Plogg smart energy meter and its award winning work on the Plogg Network controller. Its recently launched SnapUI Windows CE User Interface build tool which cuts development times by simplifying the graphic design element of compelling UIs will also be demonstrated on the stand.

www.bytesnap.co.uk (091076-I)

Gas station and convenience market fitted with 100% LED lighting

The promised energy efficiency and savings as a result of LED based lighting solutions is proving a reality at Morrisons' Illingworth gasoline station and convenience market in the United Kingdom. The solution, created by Philips Lighting, demonstrates the benefits and appropriateness of LUXEON Rebel based luminaires for both internal and external applications. Most importantly, the LUXEON based solutions from Philips have enabled Morrisons to make substantial energy efficient gains without compromising performance.The entire site at Illingworth from the canopy and the car-wash to the signage and refrigeration cabinets utilizes high power, high efficacy LUXEON Rebel LEDs and Morrisons now enjoys impressive energy savings of approximately 45% across the installation.



Philips Mini 300 luminaires with LUXEON Rebel have replaced the old style 250 W metal halide fittings and by incorporating motion detection, the solution efficacy is further increased. Efficacy gains are not made at the expense of quality illumination.
The signage requirements on site were realized using the revolutionary new Philips Poster Box Module 300 Series (patent pending) in all of the site's illuminated signs. Aluminium profiles wash light across the sign and make optimal use of the light by re-cycling
it in the box. LUXEON Rebel LEDs are used here as well and the result is a uniform light without the stripes usually associated with fluorescent tubes. Not only is energy consumption reduced by over 75%, the long service life of the product contributes to significantly reduced ongoing maintenance costs.
At Illingworth, accent lighting for selected

merchandise such as driving accessories and seasonal goods was achieved utilizing adjustable 10 watt Spot LEDs. The long useful life of the LUXEON LED light sources means that maintenance costs are significantly reduced and no re-lamping should be required throughout the life of the store.

www.philipslumileds.com (091076-II)

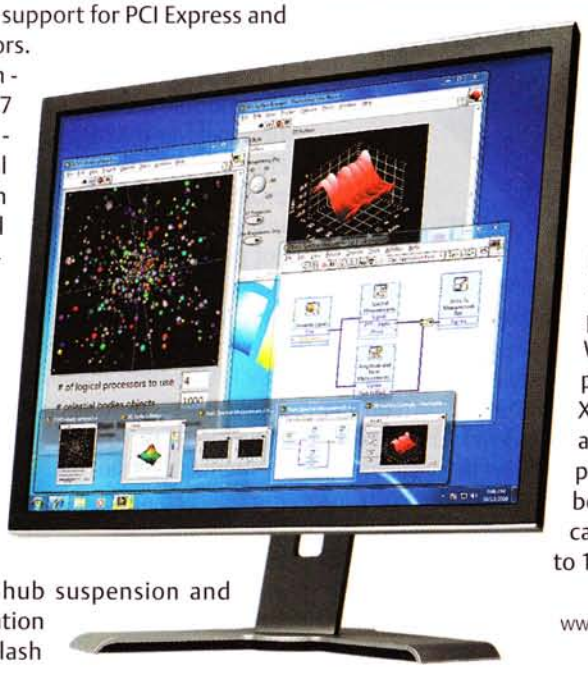
National Instruments tools integrate with Windows 7

National Instruments has announced software and hardware compatibility with Windows 7 to help engineers and scientists attain faster performance and higher throughput within their applications. Engineers and scientists who are considering upgrading to the latest computer hardware can take advantage of several new features in the new operating system. This release, which includes performance and usability enhancements, provides a smooth upgrade experience and improves the environment for hardware and software compatibility, making it ideal for measurement and workstation applications. Windows 7 contains features that provide increased USB data acquisition throughput and take full advantage of multicore processors to improve responsiveness and offer compatibility with the latest computer technologies, including support for PCI Express and 64-bit processors.

By combining Windows 7 with the LabVIEW graphical design platform for test, control and embedded system development, engineers and scientists can achieve efficiency gains including elimination of non-necessary timers, selective hub suspension and lower enumeration time for USB flash devices, which increase the performance of USB test and measurement devices. In recent benchmarks of the new NI CompactDAQ chassis with LabVIEW, engineers observed a 10 percent increase in overall attainable bandwidth in Windows 7 as compared to the same hardware running on Windows XP. The increased hardware performance combined with the multicore optimisation of both the Windows 7 operating system and the LabVIEW development environment result in a performance increase of up to 20 percent when performing high-speed or multifunction I/O measurements.

To take advantage of these performance increases, engineers may need to install new drivers. Drivers compatible with Windows 7 are available for download from National Instruments at the website below.

Data acquisition applications written in LabVIEW and using NI hardware on a multicore computer will benefit from the improvements in Windows 7 designed to further optimise the use of these processors. LabVIEW is an inherently multithreaded software platform that assigns independent, asynchronous processes to separate threads that can be executed in parallel by separate computer cores. LabVIEW programmers can create multiple computationally intensive tasks in a single application to run in parallel and optimise the use of all available cores. Engineers and scientists can use NI drivers such as NI-DAQmx, which are also multithreaded, to efficiently create high-performance acquisition and analysis applications, without having to manually spawn and manage separate threads. A benchmark LabVIEW application with four parallel loops on a quad-core machine executes up to 8 percent faster in Windows 7, compared to Windows XP. Additionally, an NI TestStand parallel sequence benchmark application executes up to 10 percent faster.



www.ni.com/windows7 (091076-IV)

PropScope is here!

The PropScope from Parallax is a two-channel oscilloscope that's capable of reading 25 million samples per second with 10 bits of resolution over 1 V, 2 V, 10 V, or 20 V peak-to-peak waveforms. Power is provided through the USB port requiring only a single cable to connect the PropScope to any laptop or desktop PC.

A built-in expansion port allows additional capabilities and upgrades, by simply plugging in an expansion card. A PropScope DAC card is even included, providing an analogue trigger, a 4-bit digital trigger, an 8-bit digital to analogue converter, and a 4-bit NTSC/PAL output. Other cards will be available to add even more useful features.



The included software provides a traditional scope interface along with auto measurements and the ability to store and export waveforms. The software also provides features not normally available in a stand-alone oscilloscope, including a function generator, a logic analyzer, a spectrum analyser, a vector-scope, and more.

Features:

- 2 input channels
- 25 Msps Maximum Sample Rate
- 20 Vpp maximum input range (–10 V to +10 V when DC-coupled)
- 10-bit input resolution over either the entire 20 Vpp range, or selectable 10, 2, and 1 Vpp ranges.
- 1x / 10x selectable probes

The Propscope retails at $249.99 directly from Parallax USA or the equivalent in local currency from Parallax' authorised distributors and resellers.

www.Parallax.com (search 'PropScope' or '32220') (091076-III)

SMD DCF77 receiver antenna used by Racetech racing team

Racetech is a team consisting of 45 students studying vehicle construction, mechanical engineering, industrial engineering and management, geo-engineering and mining and other subjects. With teamwork they develop, construct and build a racing car they hope will enable them to participate in the German "Formula Student" racing series held at the Hockenheimring.
PREMO develops the state of the art antennas for atomic watch signal reception in the racing cars. The antenna receives the radio signal from the DCF77 station (Frankfurt, Germany) in real time, this signal is processed by the car electronics to get an accurate time value. The multiple sensor measurement system of the vehicle is synchronized with the remote data logger using this signal.



PREMO has developed the first radio clock receiver antenna in SMD technology (RCA-SMD series), in the market for applications like automotive and outdoor lamp on/off control. This component is supplied in reels to automatic assembly process by SMT pick and place machine. In VLF time receiver circuits the antenna is big component; PREMO has miniaturized this antenna to make possible using low profile PCBs with 100% integration level to avoid external cables connection manually.
The antenna is delivered after a fine tuning at PREMO, at specified frequency. This tuning process is carried out in the PREMO manufacturing line using a high reliability automatic station. This station checks the antenna performance in real time.
The new antennas are configured as L-C resonant parallel tank (RCA-SMD-77A: 1.3mH || 3.3 nF for 77.5 kHz and RCA-SMD-60A: 2.1 mH || 3.3 nF for 60 kHz) which offer a higher resistance (more than 75 kΩ) at resonance frequency (±0.2 kHz). The Standard SMD version of this new radio clock antenna (at 40 kHz, 60 kHz and 77.5 kHz) is already available in the market. Other trough-hole versions and cable connections including others resonance frequencies are under development and will be available in Q2 2010.

www.grupopremo.com (091076-V)

PIC32 development and microcontroller board with interpreted BASIC

The new ByVac BV513 utilises the familiar PIC architecture to give a USB enabled board running a PIC32 Microcontroller at 80 MHz. On board is a micro SD Card holder which the BASIC can take full advantage of. Utilising subdirectories and long file names it is compatible with the FAT16 filing system. The board is programmed via the SD Card or serially via the USB, programs can be stored on RAM, Flash or the SD Card. There is an on board Flash loader so the BASIC application or any other software can be upgraded via the USB, there is no need for a specialised programmer. All operations are done serially at a superfast 2M Baud. The BV513 is aimed at beginners, utilising the BASIC interpreter and professionals because all of the hard work is done. The BASIC is unique in that

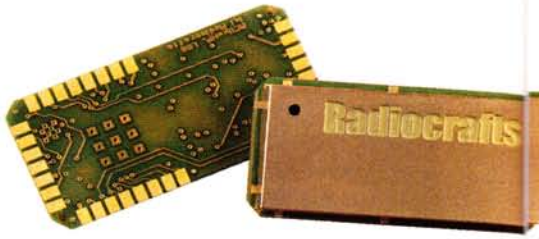


it will interface with C programs written as Plug-Ins giving the full advantage of BASIC interactivity and the speed of C. Basic functions can even be scheduled to run at given intervals. All of the documentation is on line at the Byvac website (below). The board is available now and supplied in three forms, without sockets, with sockets fitted downwards for plugging into a mother board and with turned pin sockets for breadboarding. Prices start from £16.50.

www.pic32.byvac.com (091076-VI)



Low cost, high performance ISM band RF modules at 2.4 GHz



Radiocrafts AS now expand their product line with two new modules, the low cost RC2500-RC232 and RC2500HP-RC232. These are multi-channel RF transceivers with embedded protocol. RC2500 is below US$10 in volume. The RC2500HP includes a range extension LNA and 100 mW PA. The new modules have numerous applications in M2M communication, sensor and control networks.

The module is a complete RF system solution including a high performance multi-channel FSK radio transceiver and a packet protocol handler, with an easy-to-use UART interface. The embedded RC232™ protocol provides a point-to-multipoint solution with individual addressing or broadcast, and CRC check for signal integrity. The module can also be used as a wireless RS232 / RS485 cable replacement.
The compact module, measuring only 12.7 x 25.4 x 3.3 mm, makes up a complete RF modem in one single tiny package, replacing tens of components compared to a discrete design. No external components are required, except an antenna. The modules are delivered on tape and reel for efficient volume production. It's small size and low power consumption makes it ideal for

Linx and Parallax co-sponsor $3,000 RF design contest

Linx Technologies Inc. announced an RF design contest jointly sponsored with Parallax Inc. The contest is based on the new Parallax 433 Transceiver board which incorporates the Linx LT Series transceiver. This easy to use and low cost module is capable of sending and receiving serial data wirelessly between microcontrollers or to a PC, enabling the creation of applications limited only by the designer's imagination. Three thousand dollars in cash prizes as well as numerous product giveaways will go to winning designs. Contest registration is underway and open until April 30, 2010. All entries must be received by May 31, 2010. Elektor readers are expressly encouraged to participate!

www.parallax.com/tabid/821/Default.aspx (091076-VII)

integration into size constrained battery operated equipment.
The modules are based on a new very low cost platform, and have been developed for volume applications with a price target of less than US$10 at 50k. The new modules are pin compatible with the RC11x0 series giving the customer a complete range of replaceable modules at 433, 868, 915 and 2450 MHz.
The RC2500-RC232 and RC2500HP-RC232 (set to 10 mW) are pre-certified for operation under the European radio regulations for license-free use. When used with quarter-wave antennas a line-of-sight range of 1,000 and 3,500 meters (3,000 to 10,000 ft) respectively, can be achieved at low data rates. Both modules are also designed for operation under the FCC regulations. Modules and Demo Kits are available now.

www.radiocrafts.com (091076-VIII)

Atmel and H&D Wireless deliver world's most power efficient embedded Wi-Fi solution

Atmel® Corporation is collaborating with H&D Wireless to deliver an IEEE802.11b+g Wi-Fi solution for Atmel's 32-bit AVR® microcontrollers. In this collaboration, H&D Wireless will provide the SPB104 Wi-Fi extension board which is easily connected to the AVR32 UC3 evaluation kits through the SD card socket. This collaboration results in the industry's most power efficient Wi-Fi solution, with an overall power consumption five times lower than any other similar solution on the market.



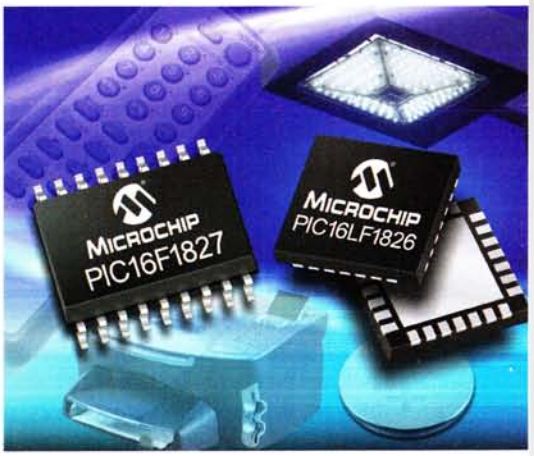
Atmel's AVR32 MCUs claim to achieve the industry's lowest power consumption with 0.48 mW / MHz in active mode, 1.5 µA with RTC running and below 100 nA in shutdown mode.
H&D Wireless' modules offer Wi-Fi capability for the 802.11b+g spectrums with a throughput of 1 to 54 Mbps. The device offers 150 µW sleep power consumption, 2.4 years of battery life, 220 mW TX power and an interface compatible to SDIO and SPI. In addition, the RF power output is 7-8 dB higher than the average on the market at +17.5 dBm.

www.atmel.com/wifi www.hd-wireless.se

18-pin PIC® micros feature enhanced mid-range core and extreme low power consumption

Microchip announces the PIC16(L)F1826 and PIC16(L)F1827 general-purpose 8-bit microcontrollers (MCUs) — the latest PIC® MCUs to feature the Company's Enhanced Mid-range core. With this extension into the 18-pin range, the PIC16(L)F1826/7 MCUs provide an advanced peripheral set that includes an mTouch™ capacitive touch-sensing module and dual I²C™/SPI interfaces, along with 'LF' versions featuring industry-leading low power consumption via Microchip's nanoWatt XLP eXtreme Low-Power technology. The introduction of these MCUs' provides an excellent low cost, pin-compatible migration path for legacy 18-pin PIC MCUs, while delivering increased performance and industry-leading low power operation.

With Microchip's Enhanced Mid-range architecture, the MCUs provide a 50% increase in performance and 14 new instructions that make programming with the C language more efficient, resulting in up to 40% better code efficiency over previous-generation 8-bit PIC MCUs. In addition to the mTouch capacitive touch-sensing module and dual I2C/SPI interfaces, peripheral enhancements include enhanced PWM functionality, and a Digital Signal Modulator that enables designers to customise communication interfaces and combine many functions into a single MCU.



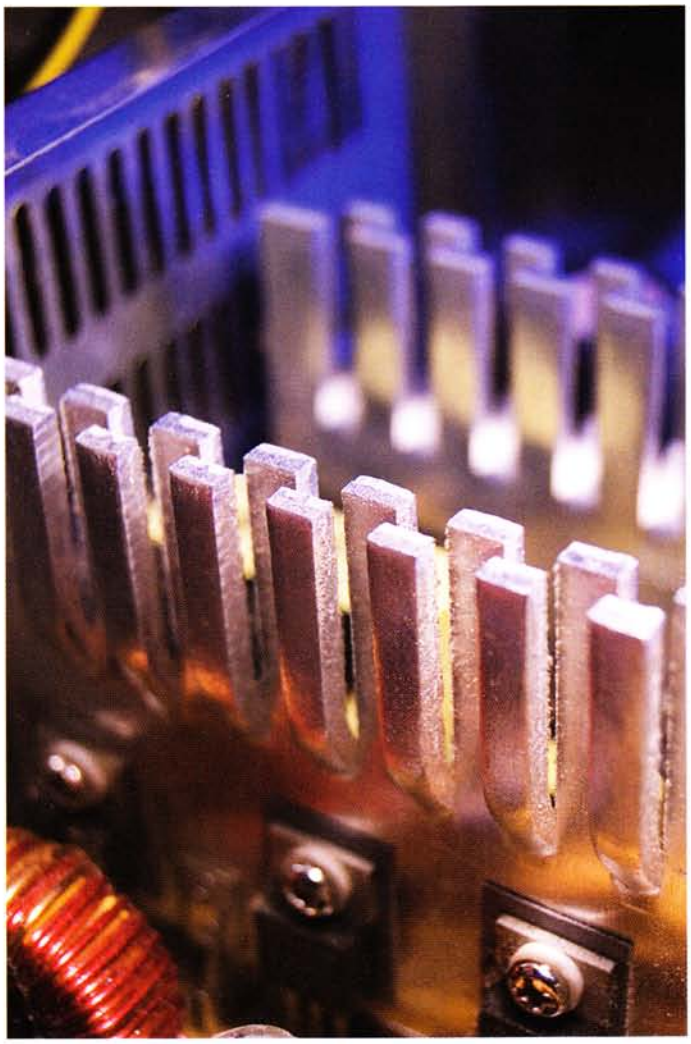
The integration of Microchip's nanoWatt XLP technology, which lowers standby current to just 0.030 µA at 1.8 V (typical), delivers market-leading current consumption, further improving overall energy efficiency and extending battery life in a broad range of applications.
The PICkit™ 2 18-pin Demonstration Board (part # DM164120-4, $23.99) provides a quick and easy way to evaluate and develop with the PIC16(L)F1826/7 MCUs. The board includes four LEDs, a potentiometer for an Analogue-to-Digital Converter (ADC), a pushbutton, a prototyping area, a 6-pin connector for the PICkit™ 3 In-Circuit Debugger/Programmer (part # PG164130), as well as two bare boards for designers to use for their own project.

(091076-XII)

Tailored Cooling

Online help for heatsink dimensioning

By Harry Baggen (Elektor Netherlands Editorial)



Too many electronic circuits produce a certain amount of heat, which must be dissipated quickly and effectively to ensure proper component operation. All sorts of heatsinks are available for this purpose, but how can you calculate how much cooling you need, and how can you choose the right heatsink? Help is available on a variety of websites.

The saying 'Where there's smoke, there's fire" most likely originated before the era of electronic circuits, as otherwise we would probably say, 'Where there's electronics, there's heat.' When electrons flow through an electronic component, they generate heat. This occurs not only as a result of the circuit design, such as with a class A audio amplifier, but also because semiconductor devices never have ideal characteristics. In digital circuits, where the devices only switch between ground potential and the supply voltage, you might expect that no heat dissipation would occur. However, it does occur due to the finite switching times of digital components. If you add to this the fact that nowadays everything must operate at the highest possible clock rate, it's easy to understand why heat dissipation is not limited to analogue circuits.
In order to ensure that analogue as well as digital components have a long useful life, it is essential to keep the temperature of the silicon chips within limits. This is usually achieved with the aid of heatsinks, which are available in all sorts and sizes. Unusual solutions, such as heat pipes, Peltier coolers and liquid cooling, can be used in special situations. However, they are rarely used in prototyping, where at most you might use a fan for forced-air cooling.

Heatsink calculations

Heatsink calculations are most often necessary with analogue circuits, such as voltage regulators or power amplifier ICs. In such cases, you usually know how much power must be dissipated and how the circuit will be fitted in an enclosure.
In the same way as with an electrical circuit, heat transfer can be calculated using thermal resistances, thermal differentials and heat flows. The semiconductor chip acts as a thermal source, which produces a certain amount of heat. The thermal differentials are the temperature differences across the various thermal resistances arranged in series. **Figure 1** shows an example of a thermal circuit diagram, which you have probably seen before in electronics books or application notes. The various components of this diagram are described briefly below.

The first thermal resistance ($R_{th\ j\text{-}mb}$) is located between the junction of the semiconductor device and the device package, which is called the mounting base or case (c). The next thermal resistance is located between the device case and the heatsink and is designated $R_{th\ mb\text{-}h}$. The value of this resistance depends on the material between the case and the heatsink, such as an insulating pad and/or thermal paste. Resistance $R_{th\ h\text{-}a}$ represents the interface between the heatsink and the ambient medium (usually air). The diagram also shows a thermal source that supplies a heat flow P.

The value of the first resistance $R_{th\ j\text{-}mb}$ is stated on the data sheet of the semiconductor device manufacturer. While you're looking at the

data sheet, you should also note another value that you will need for heatsink calculations: the maximum allowable semiconductor junction temperature T_j. This value should never be exceeded, as otherwise the life of the device will be shortened dramatically. The value of the thermal resistance $R_{th\ mb\text{-}h}$ depends on how the device is mounted. It is fairly low if the semiconductor device is fitted directly to the heatsink. It can be reduced even further by using thermal paste. If insulated mounting of the semiconductor device is necessary, you can choose from a variety of insulating materials, such as silicone rubber or aluminium oxide (alumina). The manufacturers of these materials also specify their thermal resistances. Finally, you have the thermal resistance from the heatsink to the ambient ($R_{th\ h\text{-}a}$). You can obtain this value from the data provided by the heatsink manufacturer. The specified value usually applies to a black heatsink with vertical fin orientation. If the heatsink has a natural aluminium finish instead of a black finish, the thermal resistance can be assumed to be around 10% higher. If the heatsink is fitted with the fins horizontal instead of vertical, the thermal resistance can easily be 20 to 40% higher than the stated value. If it is fitted inside an enclosure, the air flow will be reduced considerably, which considerably increases the effective thermal resistance of the heatsink.

When dimensioning a heatsink, you should always base you calculations on the maximum power dissipation of the semiconductor device. For instance, if the maximum voltage over a voltage regulator is 6 V and the maximum current is 1 A, it must be able to dissipate at least 6 W. You should aim to ensure that the temperature of the semiconductor device never exceeds the maximum allowable value, and it is better to stay somewhat below this limit. With a maximum junction temperature of 175 °C and an average ambient temperature of 25 °C, the total temperature difference over all of the thermal resistances must not exceed 150 °C. Given the amount of power to be dissipated, the total thermal resistance can be calculated as

$$R_{th\ total} = \Delta T/P = 150/6 = 25\ °C/W = 25\ K/W).$$

If the temperature regulator IC is packaged in a case with a thermal resistance $R_{th\ j\text{-}mb}$ of 5 °C/W and the IC is fitted directly to the heatsink without an insulating tab, so that $R_{th\ mb\text{-}h}$ is very low (around 0.1–0.2 °C/W), you will need a heatsink with a thermal resistance less than 20 K/W because the thermal resistances are in series and their sum must be no higher than the calculated value. Heatsinks of this sort designed for PCB mounting are readily available.

This completes our overview of the principles of heatsink dimensioning. In practice, you need to be especially careful with the details when large amounts of power must be dissipated. A variety of insulating pads and thermal pastes are available nowadays, and you should pay attention to a variety of properties such as the mounting method, maximum insulation voltage and hold-down force when making your selection.
An excellent article on the subject of cooling electronic components [1] can be found on the Elliot Sound Products website.

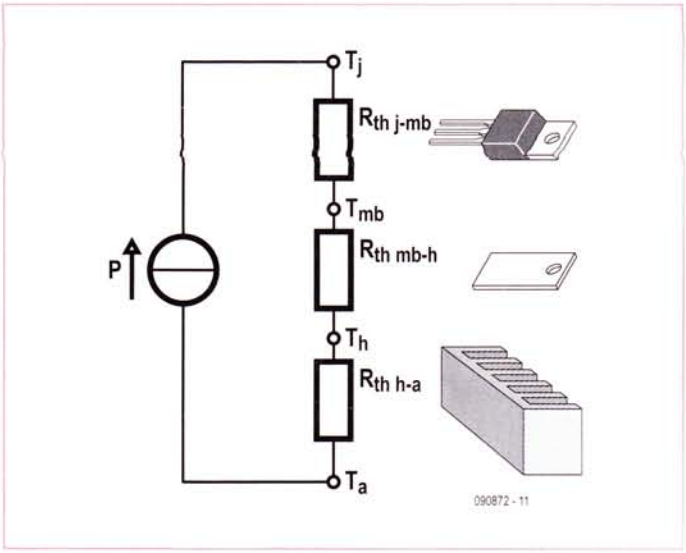


Figure 1. Thermal circuit for heatsink calculations.

Web-based help

There are a lot of websites that can help you with heatsink dimensioning and selection. Most of them have a calculation page where you only need to enter a few basic values. Here we describe a few of the more interesting sites.

Online calculations

The German heatsink manufacturer **Alutronic** provides a handy calculation program called 'Alutronic RthK Calculator', which you can download after registering on the site. There is also an online version of this program, which can be used without registration [2]. The values of the previously described thermal resistances and the amount of power to be dissipated can be set using sliders that are adjusted with the mouse, after which you can immediately see the maximum thermal resistance of the heatsink. The page also shows the maximum temperature of the heatsink, which is important information if the heatsink is mounted where it can be touched.

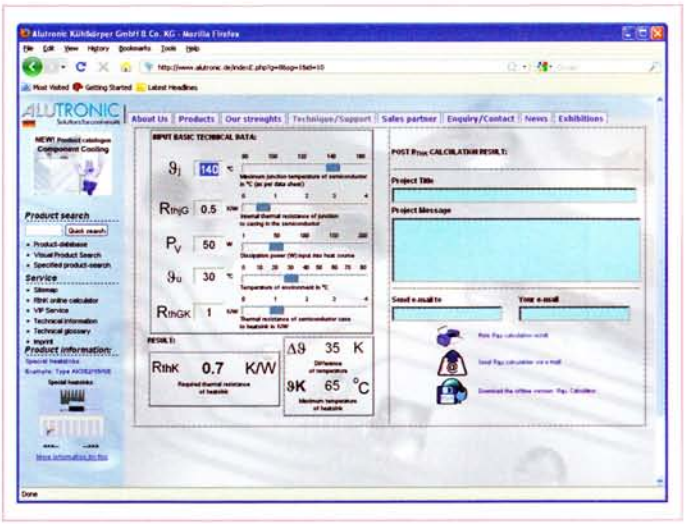


Figure 2. This online program from Alutronic lets you use sliders to set all the necessary values.

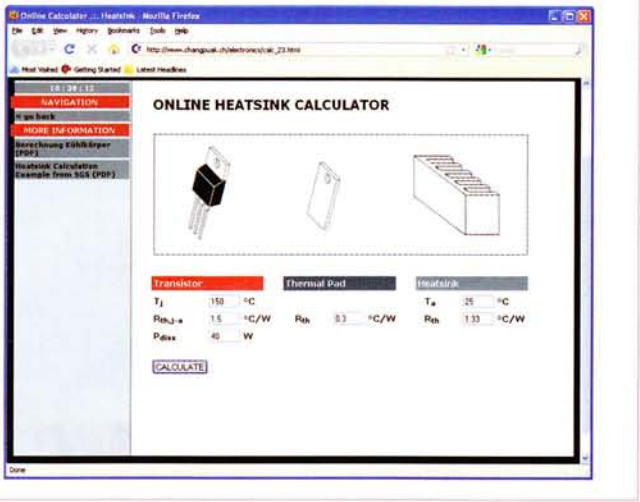


Figure 3. Clear and simple: the online heatsink calculator on the Changpuak website.

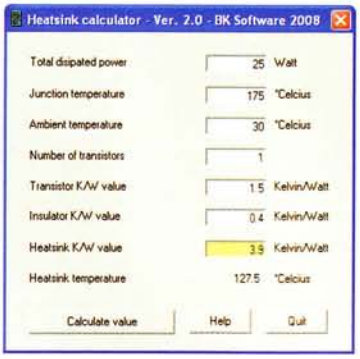


Figure 4. This free program from BK Software is small but very handy.

RS Components [3] also provides an online calculator, in this case a fairly basic version with no graphic frills. It performs the standard calculation using values that must typed in by the user. After these values are entered, the thermal resistance of the heatsink is shown.

AAVID Thermalloy is a large manufacturer of all sorts of heatsinks and related products. Various aids for heatsink dimensioning are available on this site [4].

The **Daycounter** website offers a large number of programs (more than 50) for all sorts of electronics calculations. It's certainly worth your while to have a look around here. The heatsink calculation program [5] takes the standard approach (comparable to the RS program): you type the various values in the boxes and the program calculates the thermal resistance of the heatsink. As an extra feature, this site also provides some information on the standard values of frequently used heatsinks.

The **Changpuak** site [6], which is run by a Swiss electronics enthusiast with a penchant for Thailand (hence the unusual name), also provides an online heatsink calculation program. It takes the same approach as the previously mentioned sites: you enter several values, and then it calculates the thermal resistance of the heatsink. A few illustrations clearly indicate the components associated with the values to be entered. Like the previously mentioned site, this site also offers other items of interest to electronics enthusiasts.

Stand-alone programs

Professional heatsink calculation programs are usually rather pricey (too expensive for casual use), although they offer more features in return. However, there are also heatsink calculation programs that can be downloaded free of charge. We already mentioned the stand-alone version of the RthK Calculator program from **Alutronic**. Another handy program is Heatsink Calculator V2.0 from **BK Soft-**

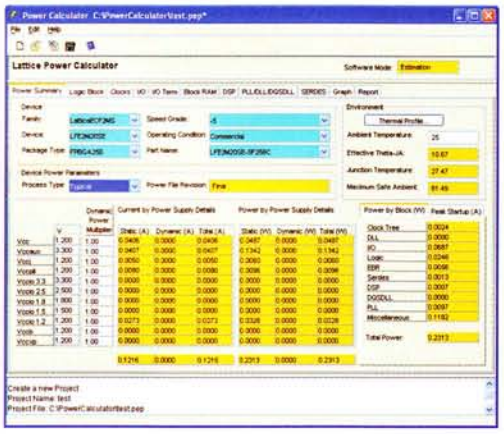


Figure 5. As you can see from the Lattice Semiconductors Power Calculator program, a lot more factors are involved in power dissipation calculations for complex digital ICs.

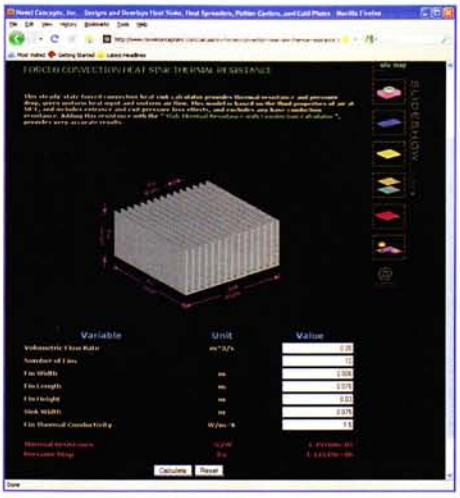


Figure 6. An online calculator for forced-air cooling is available on the Novel Concepts website.

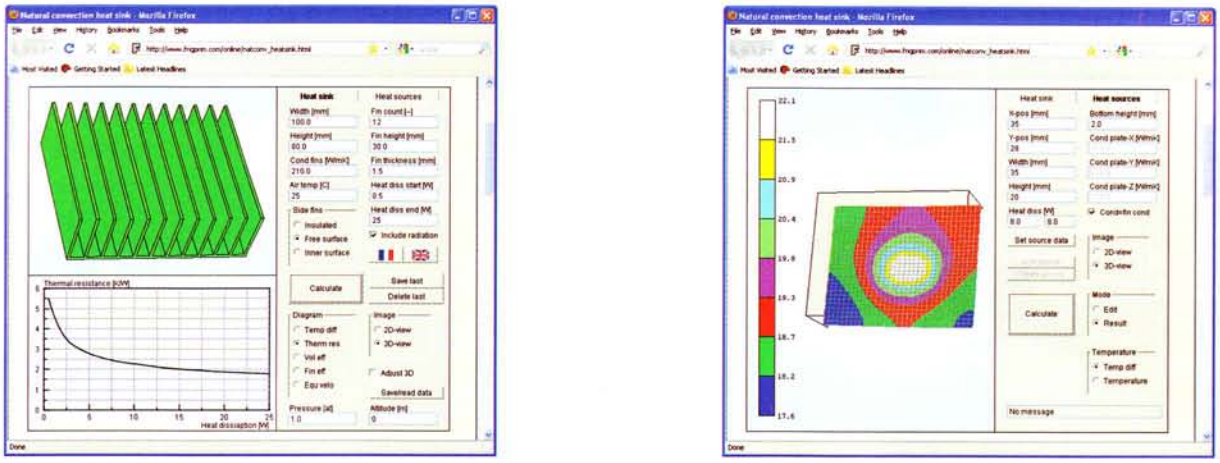


Figure 7. Frigus Primore lets you configure your own heatsink (left) and examine its characteristics, including the temperature profile over the heatsink (right).

ware, written by a Danish electronics enthusiast. This program can be downloaded from his website [7]. The nice thing about this program is that you can choose which value you want to have calculated. You enter all the known or desired resistance values and leave the box of the value you want to know empty. This value is shown after you press the button. This means that in addition to calculating the maximum allowable thermal resistance of the heatsink as with the other programs, you can also determine the maximum allow-



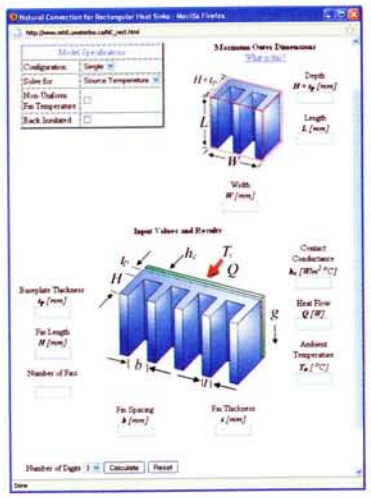


Figure 8. The Microelectronics Heat Transfer Laboratory site also enables you to configure a heatsink according to your specific wishes.

able ambient temperature for a given power dissipation when you use a particular heatsink. You can also perform calculations with more than one transistor on the same heatsink.

Of course, we shouldn't restrict our attention to analogue applications. Heat dissipation is a significant factor in the digital world as well, especially with complex ICs such as the CPU in your computer. Specifically for its own ICs, **Lattice Semiconductors** offers the Power Calculator program [8], which you can use to calculate the power dissipation of Lattice FPGAs and CPLDs along with the necessary heatsink. **Altera** offers a similar program for its own ICs, which takes the form of a spreadsheet called PowerPlay [9]. These programs are a good deal more complex than standard heatsink calculation programs.

Forced-air cooling or custom dimensioning?

The **Novel Concepts** website [10] has a program for heatsinks with forced air cooling (using a fan), which provides an easy way to determine how much power a heatsink with a given set of dimensions can dissipate in combination with a particular air flow. For this purpose, you enter the dimensions of the heatsink and the number of fins, as well as the expected speed of the air stream along the fins. This site also has several other calculators for specialised cooling calculations.

Of course, you may wish to design your own heatsink, or maybe you have a collection of several types of heatsinks for which you do not have any specific data available. In such cases, the websites mentioned below can be very helpful.

The website of **Frigus Primore**, a company that specialises in thermal calculations, offers a variety of special programs for all sorts of thermal calculations. Some of them have demo versions that can be downloaded and used for a limited period. The online heatsink dimensioning program available here [11] is especially interesting. You can use this program to configure your own heatsink (dimensions, number of fins and fin height) and then calculate its thermal resistance, temperature rise per watt and several other things, all online. In addition, a three-dimensional drawing of the heatsink is displayed, and you can rotate it in all directions using the mouse. You can then use the 'Heat Sources' tab to view the temperature profile over the heatsink, with the option of specifying exactly where the component is attached to the heatsink and the dimensions of the component. Very enlightening!

On the website of **Microelectronics Heat Transfer Laboratory** (MHTL), you can also dimension a complete heatsink yourself and calculate its characteristics using the Natural Convection for Rectangular Heatsinks program [12].

Overview

There are many manufacturers of heatsinks and related products, such as thermal pastes and insulation materials. A good starting point for looking for a suitable product or solution is the overview available on the **Heatsink Guide** site [13]. Although it's certainly not complete, it does cover a lot of suppliers and sources.

If you're looking for an extensive, practically oriented description of heatsink calculation and fitting, you should certainly read through the 'Heatsinks' article published in 1994 [14].

(090872)

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[8] www.latticesemi.com/products/designsoftware/powercalculator.cfm

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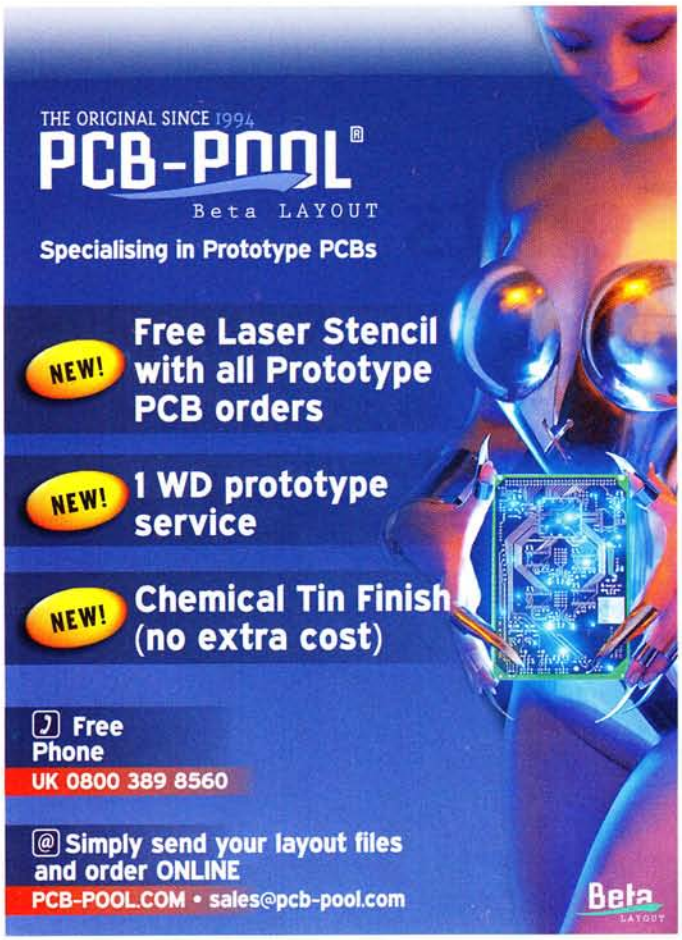
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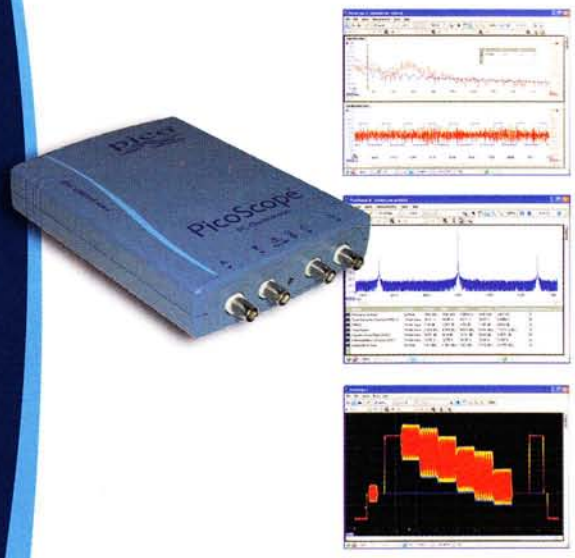


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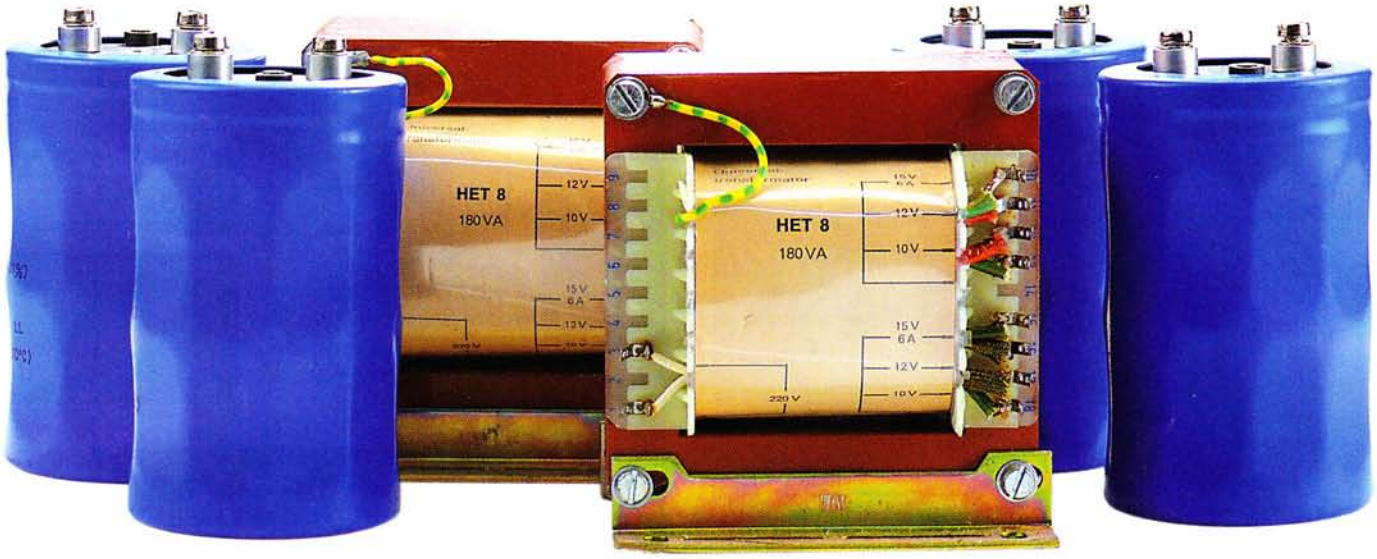
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Stable Starting Points

An introduction to electronic power supplies



By Thijs Beckers (Elektor Netherlands Editorial)

Practically every electronic circuit needs one: a power supply. The most common source of energy for all our circuits is the AC power outlet. The function of a power supply is to turn this voltage into something more useable. What do you have to look out for when it comes to designing this elementary part of a circuit?

The simplest supply is of course a type that uses a single rectifier. This is followed by the full-wave rectifier. When an electrolytic capacitor is added to this the resulting output begins to look like a reasonable DC voltage. A choke can be added in series (see **Figure 1**) in order to reduce the inevitable ripple at the output.

When more stability of the DC voltage is required some further action is needed. The easiest is the addition of resistor and a zener diode (see **Figure 2**). This simple solution is suitable for currents up to about 50 mA (depending on the voltage). The circuit is often enhanced with the use of a transistor, where the voltage across the zener diode is used as a reference voltage. The regulated output voltage is then about 600 to 700 mV less than the zener voltage. The value for R in kilo-ohms has to be chosen such that the zener diode is properly biased and sufficient current can flow through the base of the transistor:

$$R = (V_i - V_o) / (I_L + 5)$$

where I_L is in mA. The next step (and one that is very easy to implement, see **Figure 3**) is to use one of the voltage regulators from the well-known 78xx and 79xx range, which are series regulators with three pins.

The 78xx range regulates positive voltages, whereas the 79xx range is meant for negative voltages. These devices have made life very easy when there is a need for a symmetrical, stabilised power supply. The built in diodes at the outputs of the regulator ICs protect them from potential latch-ups when they're switched on.

Voltage regulators come in several other varieties. The LM317 (positive voltages) and the LM117 (negative voltages) have an adjustable output; if you need more current, there is the LT108x range which can supply up to 7.5 A.

Design criteria

When selecting the transformer you have to take the losses in the components and the expected ripple into account. The minimum required transformer voltage can be calculated using this formula:

$$V_{AC} = (V_O + \Delta V_{min} + V_R + 2V_D) / \sqrt{2}$$

Where V_O = output voltage, ΔV_{min} = minimum voltage drop across the regulator IC, V_R = ripple voltage at the input of the regulator, V_D = voltage across the rectifier diode.

A good approximation for the ripple voltage (V_R) can be obtained using the following rule of thumb:

$$V_R = I / 2fC$$

where I is in ampères and C is in farads. The frequency depends on the type of rectifier used (half wave or full wave).

All other values can be found in the data sheets for the components used.
A small tip: Consider using Schottky types for the rectifying diodes. These can make the required AC voltage *just* low enough so you can choose a transformer with a lower output voltage.
You have to keep the following in mind when selecting the (bridge) rectifier and the smoothing (reservoir) capacitors: the electrolytic capacitors are only charged up for a relatively short period, which is when the voltage from the rectifier is larger than that stored in the capacitor(s), see **Figure 4**. This results in large spikes in the charging current. The area underneath the current spike corresponds to the power that the circuit has drawn from the electrolytic capacitor and which therefore has to be replenished by the rectifier. In order to reduce the ripple voltage, larger electrolytics are often used. The consequence of this is that although the ripple voltage is reduced, the time available to the rectifier to recharge the electrolytic is also reduced. Assuming that the power consumption is the same, the size of the current surge will increase significantly (the area under the graph remains the same), which can have more serious consequences (such as burnt-out rectifying diodes).

In practice the transformer will be the largest limiting factor for the peak current. It will go into saturation fairly quickly and won't be able to supply the theoretical current requested of it. When it comes to selecting the diodes for the rectifier you can use the following rule of thumb: The maximum current that the diodes have to withstand is $\sqrt{2}$ times the peak current that the secondary winding of the transformer can deliver. To be on the safe side we normally specify twice this peak current. Don't forget that with the large currents involved it will often be necessary to put heatsinks on the rectifiers to keep them cool. A good approximation for the values to use for the electrolytics is that you need about 2200 µF per Amp.

Internet

For more complex designs such as switch-mode power supplies there are tools and programs available from several (semicon-

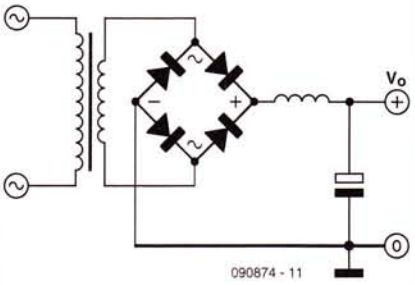


Figure 1. A bridge rectifier, a choke and an electrolytic capacitor are enough to provide a reasonably constant voltage.

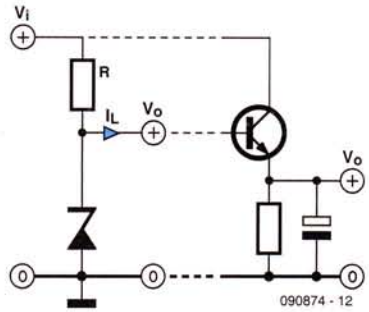


Figure 2. The addition of a zener diode as a reference increases the stability of the output voltage.

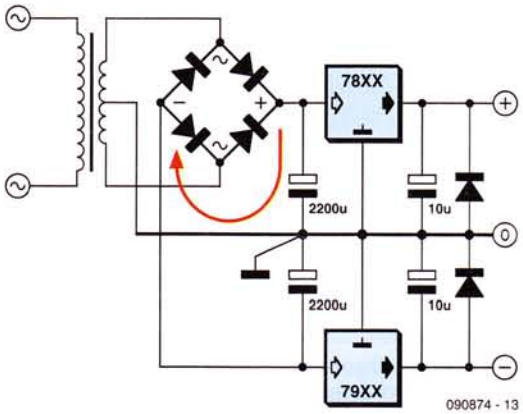


Figure 3. Thanks to integrated voltage regulators such as those from the 78xx and 79xx range the creation of stable supplies has become child's play.

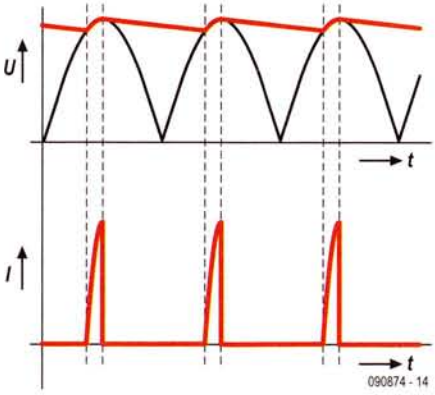


Figure 4. The peak current that occurs during the charging of the electrolytic capacitors can become quite large.

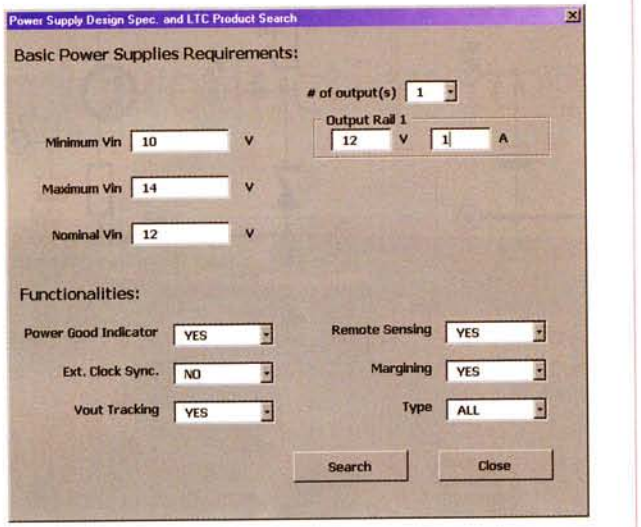


Figure 5. The program LTpowerCAD supplied by Linear Technology lets you specify a large number of parameters for your power supply.

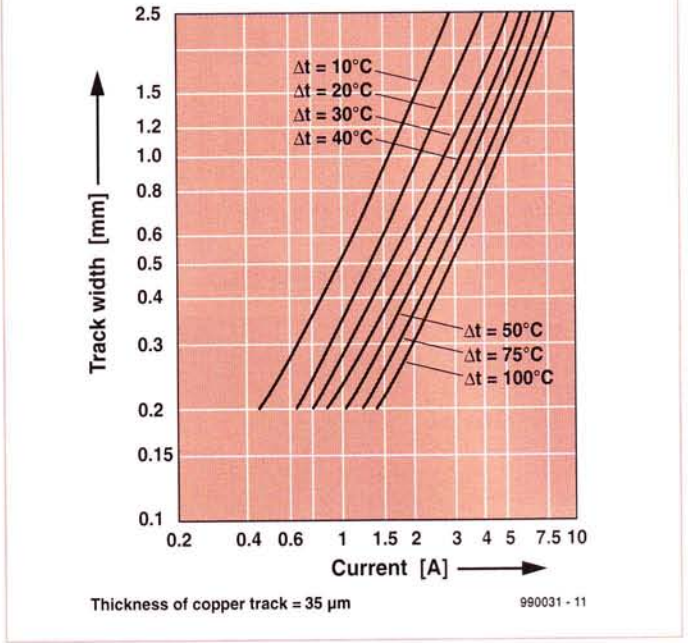


Figure 6. This graph shows just how easily PCB tracks can heat up.

ductor) manufacturers. An example of this is the 'program' *LTpowerCAD* [1] from Linear Technology. With this Microsoft Excel based tool it is very easy to design a (switch-mode) power supply that satisfies all the parameters specified on the form (see **Figure 5**). The online tool *Webench Power Designer* [2] from National Semiconductor also bursts with options and features. This list can be extended with the tools from Fairchild [3], *VIPer Design Software v.2.24* [4] from STMicroelectronics and *SwitcherPro* [5] from Texas Instruments. These are probably the most well-known. Bear in mind that most of these programs are only suitable for use with (a certain range of) special ICs made by the manufacturer in question. All of them are however free to use.

For those of you who would like to find out more about designing switch-mode power supplies, take a look at the website at www.smps.us. This site contains a huge amount of information on the subject, including an overview of the topologies used [6]. Another interesting website is at www.poweresim.com. Here you can design circuits from 'Switched Mode Power Supplies' (SMPS), which satisfy all the criteria that you've specified.

PCB layout

When a circuit diagram on paper has to be converted into a PCB layout we obviously come across all sorts of physical properties and obstacles. A few tips are very useful here and we wouldn't want to keep them from you. The smoothing capacitors should be positioned as close as possible to the point that needs smoothing. This means close to the components rather than the supply. Long PCB tracks introduce extra impedance (especially at higher frequencies) that reduces the effectiveness of the smoothing. In circuits that work at higher frequencies extra care has to be taken to keep these tracks as short as possible.

Remember that current always flows in a loop. As you can see from Figure 3, current loops also play a big role in power supplies. The red arrow indicates that the supply current flows in a loop via the Ground. When calculating the total path length of the current you therefore also have to consider the length of the Ground track (or Ground plane if it exists).
The peak current into the electrolytics that was mentioned earlier also flows via the Ground connection. To avoid unwanted interference in 'heavy' power supplies it is best to keep this current loop outside the Ground plane. This is done by wiring this separately and to choose the connection between the two large smoothing capacitors as the Ground point (where the Ground symbol is drawn in the circuit). This is sometimes called the star point.

Another area that should be given considerable thought when designing the PCB is the width (and thickness) of the tracks. Not only do they have a certain resistance, they can also heat up. The graph in **Figure 6** shows how much the temperature rises with certain widths of tracks and the size of the current through them. As can be seen, the temperature rises quickly as the current increases. It is sensible to limit the temperature increase to 30–40 degrees C because the graph shows the rise under ideal circumstances. Once the PCB has been mounted inside a case it can't lose the heat as easily and the temperature could rise much further, which could have disastrous consequences on the circuit...

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Internet Links

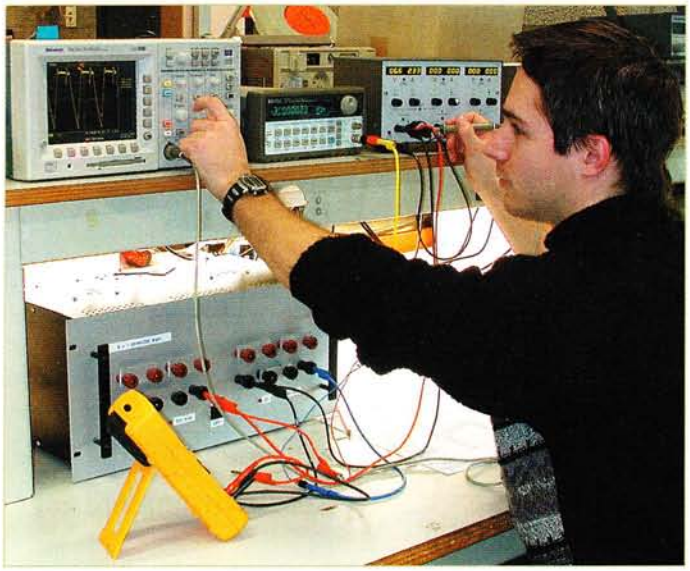
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Torture Rack

Dynamic testing of power supplies using simple tools

By Harry Baggen (Elektor Netherlands Editorial) and Ton Giesberts (Elektor Labs)

How can you find out how stable a lab or benchtop supply is? You can get a good impression of the stability of a power supply under various conditions by loading the output dynamically. This can be implemented using just a handful of components.



Apart from obvious factors such as output voltage and current, noise, hum and output resistance, it is also important that a power supply has a good regulation under varying load conditions. A standard test for this uses a resistor array across the output that can be switched between two values. Manufacturers typically use resistor values that correspond to 10% and 90% of the rated power output of the supply. The switching frequency between the values is normally several tens of hertz (e.g. 40 Hz). The behaviour of the output can then be inspected with an oscilloscope, from which you can deduce how stable the power supply is. At the rising edge of the square wave you will usually find an overshoot, which is caused by the way the regulator functions, the inductance of the internal and external wiring and any output filter.

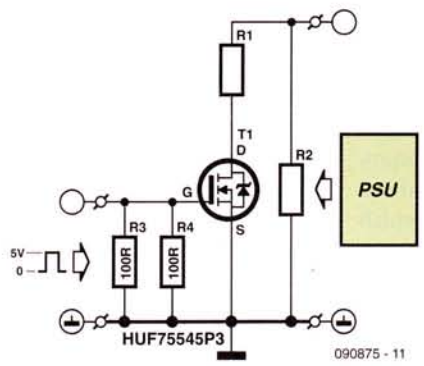
This dynamic behaviour is normally tested at a single frequency, but the designers in the Elektor lab have tested numerous lab supplies over the years and it seemed interesting to check what happens at higher switching frequencies. The only items required for this are an ordinary signal generator with a square wave output and the circuit shown in **Figure 1**. You can then take measurements up to several megahertz, which should give you a really good insight for which applications the power supply is suitable. More often than not you will come across a resonance frequency at which the supply no longer remains stable and it's interesting to note at which frequency that occurs.

The circuit really is very simple. The power MOSFET used in the circuit is a type that is rated at 80 V/75 A and has an on-resistance of only 10 mΩ (V_{GS} = 10 V).

The output of the supply is continuously loaded by R2, which has a value such that 1/10th of the maximum output current flows through it (R2 = $V_{max}/0.1I_{max}$). The value of R1 is chosen such that 8/10th of the maximum current flows through it (R1 = $V_{max}/0.8I_{max}$). Together this makes 0.9 I_{max} when the MOSFET conducts. You should round the calculated values to the nearest E12 value and make sure that the resistors are able to dissipate the heat generated (using forced cooling, if required). At larger output currents the MOSFET should also be provided with a small heatsink. The gate of the FET is connected to ground via two 100 Ω resistors, providing a neat 50 Ω impedance to the output of the signal generator. The output voltage of the signal generator should be set to a level between 5 V and 10 V, and you're ready to test. Start with a low switching frequency and slowly increase it, whilst keeping an eye on the square wave on the oscilloscope. And then keep increasing the frequency... Who knows what surprises you may come across? Bear in mind though that the editorial team can't be held responsible for any damage that may occur to the tested power supply; the use of this circuit is at your own risk!

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1



Battery Checker

One to ten cells, up to 10 A



By Rüdiger Britzen (Germany)

A battery pack is only as strong as its weakest cell. This intelligent battery checker will determine the state of cells so that an optimal selection can be made from them to form a pack. It is essential to measure not only the capacity of the cells, but also their internal resistance.

In theory it is relatively easy to determine the capacity of a battery: it is the integral of the discharge current over the time it takes a fully charged cell to reach its specified end-of-discharge voltage. This voltage is different for cells of different chemistries. In practice a single cell is discharged and the current is measured regularly.

Each measurement is made over a sufficiently short period that the current can be considered as constant over that period, at least compared to the overall accuracy of the measurement. The current measurements are summed and the result converted to a capacity in the appropriate units, usually mAh (milliampère-hour). Discharge is stopped when the end-of-discharge voltage is reached.

Criteria

When selecting cells to make up a battery pack the total capacity is not the only criterion of importance. Equally important is the internal resistance of the cells, which can be calculated by dividing the load current into the difference between the terminal voltage under load and the open-circuit terminal voltage. It is also interesting to know at what current the end-of-discharge voltage is reached and the total charge drawn from the cell to reach this point. The battery checker has a 'constant voltage' mode to make this kind of measurement, on which subject more in the section below describing the software.

In order to be able to provide adequate load for powerful cells, discharge currents as high as 10 A are needed. Commonly-available battery packs rarely consist of more than ten NiCd or NiMH cells, and so a voltage range of 0 V to 12 V is sufficient. The user interface consists of a 2-by-16 LCD panel, a three-colour (red, yellow and green) LED, four buttons, and an EIA232 interface for configuration and control. The battery voltage is measured using separate voltage sense wires to ensure that the readings taken are not affected by the voltage drop along the wires used to carry the discharge current. This voltage drop will be significant at the higher discharge currents envisaged.

The circuit

The battery checker internally uses three different supply voltages, which are generated by the circuit involving TR1, F1, B1, C1, IC1, IC2 and IC3 and associated decoupling

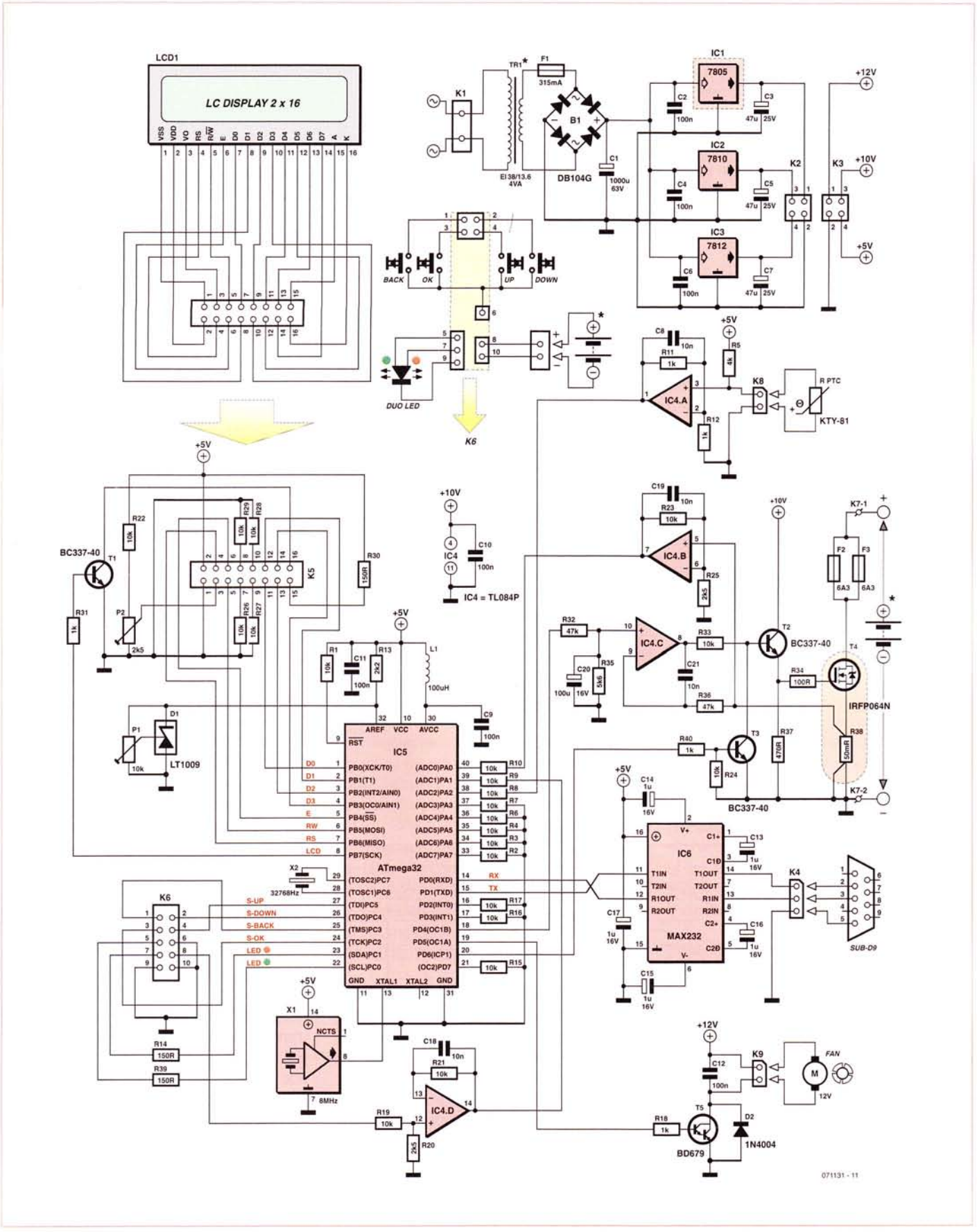


Figure 1. Circuit diagram of the battery checker. The battery under test is connected to two separate pairs of terminals, one pair to carry the discharge current and one to measure the terminal voltage.

Features

- Voltage range 0 V to 12 V (corresponding to 0 to 10 NiCd or NiMH cells)
- Discharge current up to 10 A
- Internal resistance measurement at the start of the discharge process (average of ten readings)
- Constant current discharge with switch-over to constant voltage discharge
- Display of set-point and actual values of voltage and current
- Display of discharge time, total charge, internal resistance, heatsink temperature and fan speed
- Controlled using four pushbuttons to set cell count, required discharge termination voltage and required discharge current
- Calibration facility for A/D converter and current regulator PWM
- Backlit 2-by-16 character LCD
- Status LED
- Heatsink temperature monitoring with fan control (proportional controller)
- Serial interface to output values and to receive control messages
- Maximum power dissipation 120 W (with special cooling), adjustable 40 W limit in software
- Free download of software and printed circuit board layouts at www.elektor.com/071131

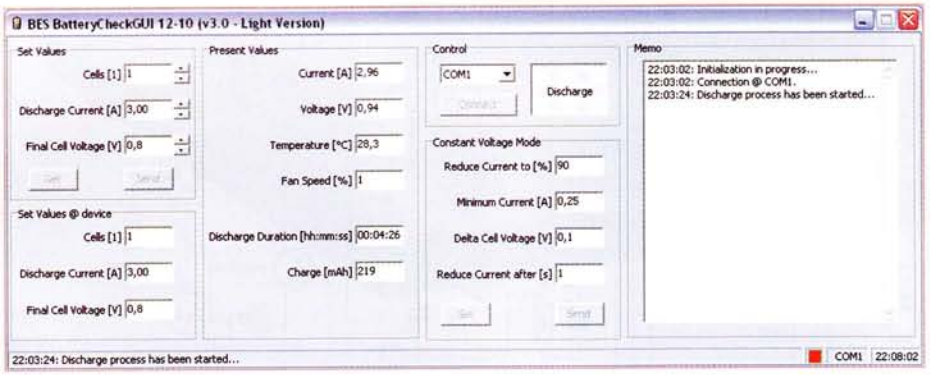


Figure 2. The Windows software displays the settings and the instantaneous measured values.

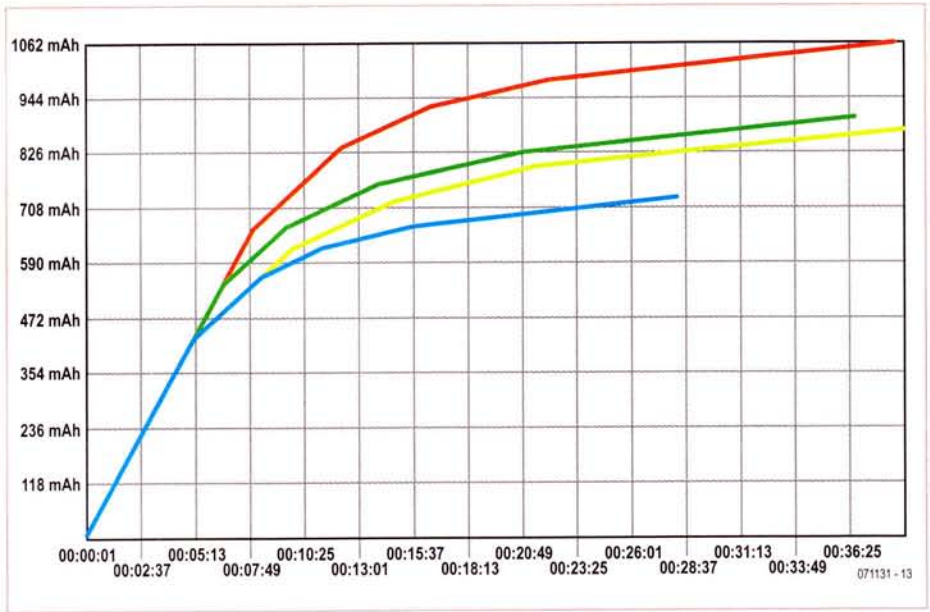


Figure 3. A planned extension to the software will feature log files and graphical output, such as this plot of charge against time.

capacitors. The voltages are: 5 V, for the microcontroller and display; 10 V, for the current regulator; and 12 V for the fan.

As is so often the case the circuit centres on a microcontroller, IC5. Around it we have an 8 MHz clock oscillator (X1), 2.56 V precision voltage source D1 used to provide a reference for the analogue-to-digital converter, watch crystal X2 and quad operational amplifier IC4.

IC4.A acts as a buffer amplifier for the PTC thermistor attached at K8, used as a temperature sensor. The opamp is wired as a non-inverting amplifier and provides a gain of 2 for the voltage dropped across the thermistor.

IC4.B is also configured as a non-inverting amplifier and provides a gain of 5 for the voltage dropped across precision shunt resistor R38: this voltage is directly proportional to the discharge current.

IC4.D buffers the battery voltage, which is divided by 5 by the potential divider formed by R19 and R20. The battery under test is connected to the circuit in two places: at K7 where the discharge current is drawn, and between pins 8 and 10 of K6, where the terminal voltage is measured. Separate connections should be made to the battery terminals from these points on the circuit, as mentioned above.

IC4.C forms part of the current regulator. A DC level, smoothed by the low-pass filter formed by C20 and R35, appears at its non-inverting input. This voltage is one tenth of the average value of the PWM signal present on PD4 (pin 18) of the microcontroller, because of the potential divider comprising R32 and R35. The output of the operational amplifier is connected to the base of T2 via R33, and the emitter of this transistor is connected to the gate of power FET T4 via the current divider formed by R34 and R37. The values of R33, R34 and R37, together with the current gain of T2 and the gate capacitance of T4, determine the characteristics of the current regulation control loop. The voltage across R38 in the drain circuit of T4 is proportional to the instantaneous discharge current flowing. This voltage is taken via R36 to the inverting input of IC4.C. There are two fuseholders for F2 and F3 (each for a 6.3 A fast acting fuse) in the source circuit of T4, as the fuseholders are

About the Author

Rüdiger Britzen, 32, studied Electronics and Information Technology at the German Army University in Munich, and works principally as a systems engineer in the defence industry. Alongside that he is also, as Britzen Embedded Systems, an independent hardware and software developer.

not rated to carry 10 A. T3 allows the current regulator to be switched off quickly by pulling the base of T2 to ground.
The circuit around IC6 is in accordance with its data sheet, converting between the TTL levels of the microcontroller and EIA232 voltage levels.

Firmware

The software running in the microcontroller is interrupt-driven. The body of the code (at main) runs after a reset and configures and initialises all the inputs, outputs and timers (Initialize, RefreshLCD). The code then enters an infinite loop, reacting to watch crystal timer overflows (every 250 ms), button presses and the reception of complete data messages, setting outputs appropriately.

Timer 0 generates interrupts at a frequency of 488.28 Hz. The service routine reads the state of the buttons and performs debouncing. Timer 1A and Timer 1B are configured as PWM generators to drive the current regulator (Timer 1B) and the fan (Timer 1A). Timer 2 is clocked by the 32.768 kHz watch crystal and overflows every 250 ms. This triggers the sending out over the EIA232 interface either of instantaneous measured values and set points (current, cell voltage, cell count, charge, discharge time and so on) or of device settings (characteristic curves, maximum values, parameters for constant voltage mode), in response to a corresponding request. Also, the interrupt flag ClockCrystalTimer is set, which causes the function CalculateValues() to be called from the main loop.

CalculateValues() first performs analogue-to-digital conversions on the battery voltage, the voltage dropped across the shunt (which is proportional to the discharge current), and the voltage across the thermistor (which depends on the heatsink temperature). These values are used to calculate settings for the fan and the discharge current (if enabled), as well as to update the running total of charge. The function also implements 'constant voltage mode' and the measurement of the internal resistance of the battery. If the heatsink temperature exceeds the value 'CSMAxTemperatureInCelsius' discharge is stopped for the time period specified by 'CSCoolDownPeriod'.
In 'constant current mode' the battery is initially discharged at a user defined current ('SetCurrentIn10mA') down to a preset voltage ('SetVoltageIn100mV' + 'CSCurrentReductionUDeltaIn100mV'). Then, as soon as the voltage ('MeasuredVoltageIn100mV') has remained below the preset level for given time ('CSCurrentReductionTime'), the discharge current is reduced in steps ('CSCurrentReductionAmount') until a minimum value ('CSCurrentReductionMinCurrentIn10mA') is reached. The unit continues to discharge the battery at this current until the final discharge voltage ('SetVoltageIn100mV') is reached. The graph of current against time gives a clear picture of the performance of the cell, and is much more informative than a bald capacity value.

The internal resistance of the battery is measured at the start of the discharge procedure. The measurement is done by first measuring the open-circuit voltage of the battery and then measuring the terminal voltage with the specified discharge current being drawn. The measurement is repeated ten times at intervals of one second. The two smallest and the two largest calculated values for the internal resistance are discarded and the remaining six values are averaged, the result being displayed on the LCD. The code to perform this calculation is unfortunately relatively involved and not necessarily very easy to understand: this part of the CalculateValues() function may be hard to modify.

The function ProcessKey() includes the state machine behind the battery checker. Depending on the current state, a keypress recognised in the Timer 0 overflow interrupt code will cause a switch to a new state or some other response.
The function RefreshLCD() writes information to the LCD panel depending on the current state of the system.

Windows software

The Windows software gives access to the basic functions of the battery checker and can also be used as a basis for expansion.
The program displays the set points for cell voltage, discharge current and cell count, and the measured values for current, voltage, heatsink temperature, fan speed, discharge time and total charge (see **Figure 2**). These set points and the 'constant voltage discharge' setting can be configured. If a value of less than 100 is entered in the field 'Reduce Current to %', the discharge current will be reduced by the given percentage factor at the end of any period longer than the time given at 'Reduce Current after' during which the cell voltage remains below the value 'Final Cell Voltage' plus 'Delta Cell Voltage'. This process repeats until the minimum discharge current is reached.
The unit's status is reflected in the status line of the window as a virtual LED, with colours corresponding to those of the LED on the unit.
After connecting the battery checker to the PC, choose the correct COM port setting and initialise communication by clicking on the 'Connect' button. If the connection is successfully made the input fields will become active and the unit can be configured and controlled.
The author is planning an expanded version of the software that will allow the display of log data, graphical presentation like that shown in **Figure 3**, and configuration of all the new settings.

Protocol

The author has developed a protocol for communications between the PC and the battery checker, using seven-byte messages to carry sixteen-bit values with eight-bit identifiers. The identifier is split into two bytes and the data value into four bytes, and a checksum is appended. The header file RBE_SP16.h and code RBE_SP16.c encapsulate the protocol and also implement a FIFO buffer.
Every 250 ms by default the battery checker send out either the set-points and measured values or, in response to a request, the core settings of the device (the variables whose names begin 'CS') as a single message with appended checksum (31 bytes in total).

COMPONENT LIST

Resistors
(5%, 0.25W unless otherwise indicated)

R1–R4, R6–R10, R15,R16,R17, R19, R21–R24, R26–R29, R33 = 10kΩ
R5 = 4.02kΩ (1%)
R11,R12,R18,R31,R40 = 1kΩ
R13 = 2.2kΩ
R14, R30, R39 = 150Ω
R20, R25 = 2.49kΩ (1 %)
R32, R36 = 47kΩ
R34 = 100Ω
R35 = 5.6kΩ
R37 = 470Ω
R38 = 50mΩ 0.5 % precision power resistor, e.g. Isabellenhütte Heusler type PBV 0.05 (Conrad Electronics # 447382-62)
P1 = 10kΩ preset, horizontal
P2 = 2.5kΩ preset, vertical

Capacitors
C1 = 1000µF 63V radial, lead pitch 10mm
C2,C4,C6, C9–C12 = 100nF 50V ceramic
C3,C5,C7 = 47µF 25V radial, lead pitch 0.1 inch
C13–C17 = 1µF 16V radial, lead pitch 0.1 inch
C8,C18,C19,C21 = 10nF ceramic
C20 = 100µF 16V, radial, lead pitch 0.2 inch

Inductors
L1 = 100 µH miniature choke (resistor body)

Semiconductors
B1 = DB104G (Taiwan Semiconductor), 1A 400V bridge rectifier (e.g. Farnell # 706796)
D1 = LT1009CLPG4 (TI), 2.5V voltage reference, TO-92 case (e.g. Farnell # 9589724)
D2 = 1N4004
IC1 = 7805 with 15 K/W heatsink
IC2 = 7810
IC3 = 7812
IC4 = TLC274BCN (TI), DIP-14 with socket
IC5 = ATmega32-16PU (ATMEL), DIL-40 with socket, programmed, order code 071131-41*
IC6 = MAX232N (TI), DIP-16 with socket
T1,T2,T3 = BC337-40
T4 = IRFP064NPBF (International Rectifier, e.g. Farnell # 8649227)
T5 = BD679

Miscellaneous
K1 = 2-way PCB screw terminal, lead pitch 7.5mm
K2,K3,K8,K9 = 2-pin pinheader, 0.1 inch lead pitch
K4 = 3-pin pinheader, 0.1 inch lead pitch
K5 = 16-way (2x8) pinheader, 0.1 inch lead pitch
K6 = 10-way (2x5) pinheader, 0.1 inch lead pitch
K7 = 2 solder pins, 1.3mm diam.
LCD1 = 2x16 characters, e.g. DEM16217 SYH-PY /V (Elektor-Shop # 030451-72)
TR1 = PCB transformer, 12V 0.33A secondary, e.g. EI38/13.6 4.0 VA (Pulse), part no.: 038-5414.0 (230V primary), 038-5402.0 (115V primary) or HAHN type BV EI 382 1191 (230V primary)
X1 = 8MHz quartz oscillator module, e.g. AEL Crystals type O8M000000L642 (Farnell # 9509712)
X2 = 32.76 kHz watch crystal, cylindrical case
F1 = fuse 0.315A 250V, slow blow, dim. 5x20mm, incl. fuseholder and cap
F2, F3 = fuse 6.3A fast, dim. 5x20mm, incl. fuseholder
9-way sub-D socket
4 pushbuttons for front panel mounting
Fan, 12VDC, 80mA, dim. 40x40mm
KTY 81-122 (NXP), PTC temperature sensor, SOD-70 case
Heatsink, Fischer Elektronik type SK 68/50 SA, dim. 50x46x33mm, rating 4.6K/W
Bicolor LED (green/red), 5mm diam.
Heat conducting glue for securing temperature sensor to heatsink
Terminal posts, 4mm diam. (1 red, 1 black)
PCB nos. 071131-1* (PSU) and 071131-2* (main board)

* Kit of parts no. 071131-71 containing PCBs, a programmed microcontroller and all parts (except case) is available from the Elektor Shop, see www.elektor.com/071131

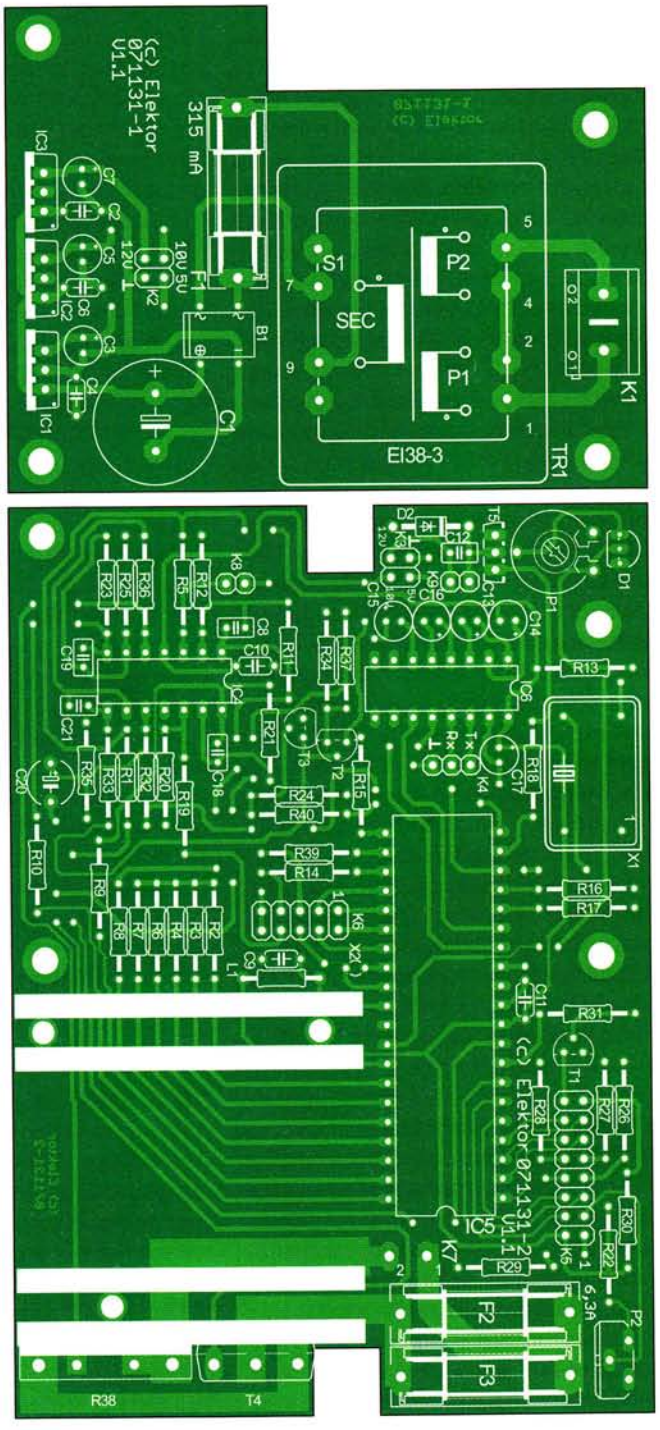


Figure 4. Component mounting plan for the power supply board and the main board.

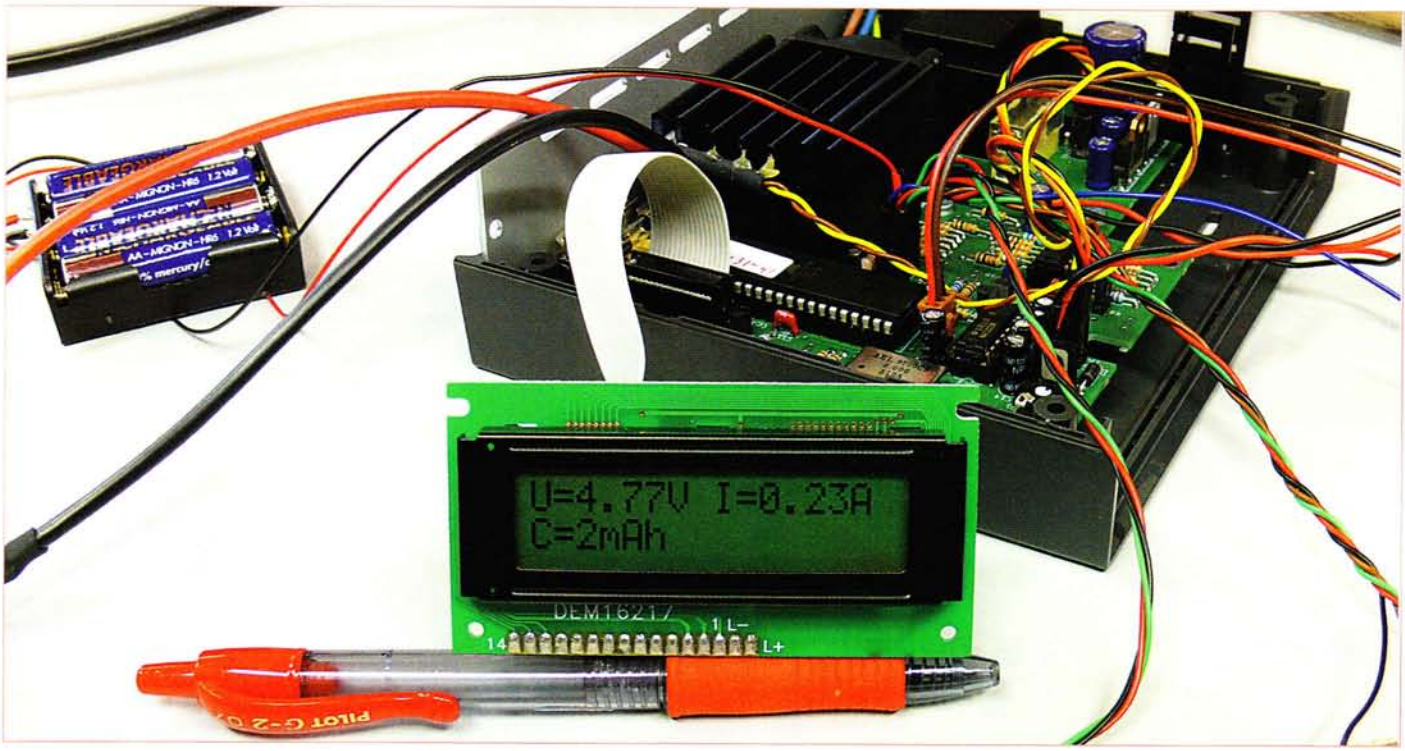


Figure 5. The Elektor laboratory prototype under test.

Construction and operation

Both the main board and the power supply board are populated exclusively using through-hole components (**Figure 4**). The tracks between the connection points for the 1.5 mm² wires (at K7), the FET and the shunt should be tinned over with extra solder (assuming the board does not have a solder mask) or reinforced using suitable soldered silver wire (if the board does have a solder mask). It is recommended to test the boards separately, starting with the power supply board. It is essential to ensure that all wires and components carrying mains voltages are adequately insulated and cannot be touched. In addition, it is advisable to use an isolation transformer. Check that the correct voltages appear on K2.

Power the main board using a laboratory supply set to a conservative current limit of say 100 mA. If nothing appears on the display, adjust P2 to set the contrast suitably.

If everything appears to be working so far, you should find operating the unit self-explanatory. Two buttons ('Up' and 'Down' navigate through the menus, the third button ('OK') confirms an input, and the fourth ('Back') cancels an operation.

With the main board connected to the power supply board, adjust P1 so that the voltage on D1 (i.e., on pin 32 of IC5) is exactly 2.5 V. The next step is to calibrate the analogue-to-digital converter (for the battery voltage and the shunt voltage) and the current regulator. To do this, go to the calibration menu and select the battery voltage ADC. Short the battery voltage measurement terminals (pins 8 and 10 of K6) together and press the confirmation button to calibrate the 0 V point. Now connect the voltage measurement terminals to as precise a 6 V source as possible and press the confirmation button again.

Next, calibrate the current regulator. Connect a voltage source capable of delivering at least 2 A to the load terminals of the battery checker (on K7), with an ammeter in series with one of the connections. Then select the appropriate menu item and adjust the PWM value using the navigation buttons to make the current in the load as close to 2A as possible. Finally, calibrate the ADC for the shunt voltage. Again, a 2 A source is required connected to the load terminals. Simply select and confirm the appropriate menu option.

The calibration values can be stored in EEPROM by selecting the 'Store settings' menu option. The text is followed by a '*' if one or more of the current settings differs from that stored in EEPROM.

The parts list does not recommend a particular enclosure for this project. The author used a TEKO CAB 022.9 enclosure for his prototype, and for the Elektor prototype we used a Retex Elbox 33030202. The parts mounted on the front panel (LCD, buttons and sockets) are connected to the relevant points on the printed circuit board using ribbon cable or wire. For the current-carrying connections wire with a cross section of at least 1.5 mm² cross-sectional area is needed.

A DIY battery holder

Ordinary battery holders and charging cradles are only really suitable for currents of up to about 3 A. A cheap plastic battery holder may start to melt around the contacts at a discharge current of 2.5 A. The problem does not arise with cells that have solder tags.

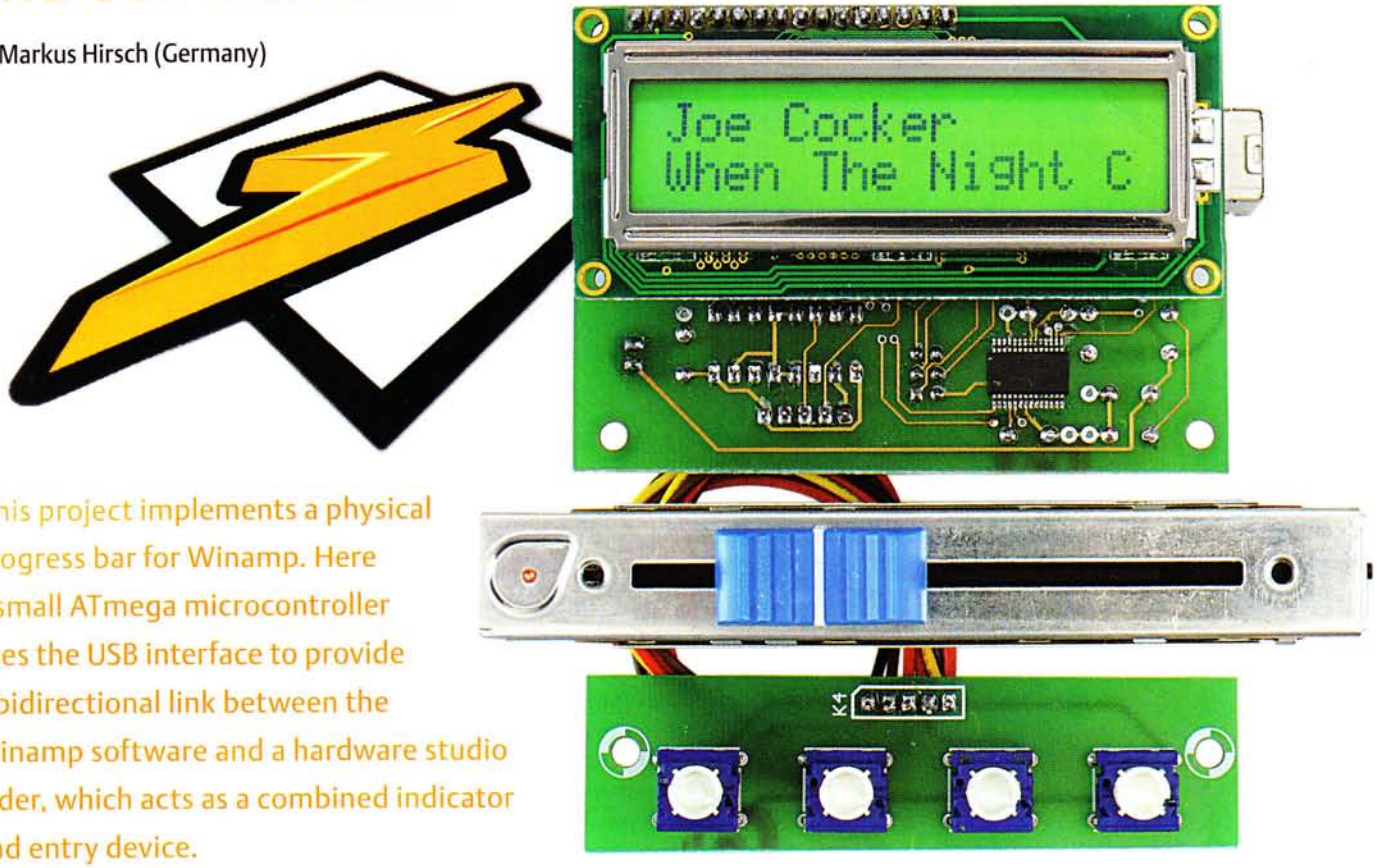
For individual cells without solder tags the author found a solution using a ratchet clamp found in a local tool shop next to the ordinary woodworking clamps. With a bit of skill it is possible to repurpose the clamp as a 'high current discharge clamp'. The ratchet clamp has a smooth action without steps and so can easily grip cylindrical cells, allowing currents of up to 10 A to be drawn without significant temperature rise. However, it is important to be careful to avoid overloading cells: during testing the author succeeded in inadvertently destroying two brand new Panasonic AA cells through overheating in constant voltage mode (U=0.9 V, current reduction after 1 s) with an initial current of 10 A.

(071131)

Winamp Controller

Winamp control unit with motorised potentiometer and USB interface

By Markus Hirsch (Germany)



This project implements a physical progress bar for Winamp. Here a small ATmega microcontroller uses the USB interface to provide a bidirectional link between the Winamp software and a hardware studio fader, which acts as a combined indicator and entry device.

A variety of remote control devices for Winamp [1] and other PC-based media players have been available for a good while. They include infrared interfaces (Winlirc), web browsers (Ajaxamp), and hotkeys on the keyboard. All of these systems have one thing in common, which is that they are limited to buttons or keys or use virtual progress bars on the computer monitor. If you want to have a complete hardware interface unit with the same level of sophistication as the virtual Winamp design, you need a physical progress bar.

The difficulty with this is that it falls outside the usual scope of electronics for electromechanical devices. The solution must be simple and reproducible, and it should be possible to build it without having your own machine shop.

A standard studio fader unit provides a suitable solution. This is a motorised potentiometer, consisting of a linear mono slider potentiometer driven by a DC motor. The potentiometer and motor assembly forms a compact unit that is easy to use (**Figure 1**). The drive requirements are also relatively simple, so it can readily be integrated with the software to serve as a physical progress bar. The software also allows its behaviour to be modified and optimised relatively easily. You can also use this project as a basis for your own modifications or extensions, since the source code of the Windows program and the AVR firmware is available [5].

Features

- Physical progress bar for Winamp
- Fast forward and reverse using a physical slider
- Power supply via USB port
- Data transfer via USB port
- Song title display on LCD module (2 x16 characters)
- Four buttons for Play, Stop, Next, and Previous
- Runs with Winamp 5.5 (tested with Winamp 5.541)

Hardware

The circuit (**Figure 2**) uses well known, readily obtainable components. It is built around an Atmel ATmega16 AVR microcontroller. Here the internal oscillator can be used, since the circuit does not require especially high processing power.

A standard LCD module is used to display the song titles. It can easily be driven using BASCOM AVR code [2]. Four simple pushbuttons connected to four I/O pins of the microcontroller are used to control the operational functions of the media player (Play, Stop, Next

and Previous). The internal pull-up resistors of these pins are enabled, which saves four resistors on the board. The buttons pull the I/O pins to ground when they are pressed.

The connection to the PC is provided by the USB port. This has the advantage that the unit can also be used with relatively new PCs that have only USB interfaces. In addition, the USB interface provides a 5-V supply voltage with sufficient current capacity, so we can dispense with an external power supply for the Winamp controller. A USB/serial converter in the form of an FT232RL IC in the circuit provides the link to the USB port. To ensure that the Winamp controller is recognised by every PC as a USB device and avoid the need to configure the Com port in the Windows program before using the controller, it is necessary to program this FTDI IC with suitable USB descriptors. This is described in more detail later on.

An L293D (IC3) is used to drive the motor of the studio fader. Only one of the two H bridge drivers in the IC is used. As the voltage (5 V) and the current (500 mA maximum) available from the USB port are both somewhat on the low side for the fader used here (see 'Practical aspects'), PWM mode is not used for driving the motor. As a result, the motion of the slider is limited to a fixed speed. The software compensates for this by working in small steps.

The feedback signal that indicates the slider position to the microcontroller is provided directly by the potentiometer, which is wired as a voltage divider connected between the 5 V supply voltage and ground. The wiper of the potentiometer is connected to pin 4 of connector K2, which in turn is connected to I/O pin PA4 of the ATmega. This pin is configured as the input of the internal A/D converter. The voltage on the wiper of the potentiometer is thus digitised and processed in the software as the position value.

As a component designed for use in audio mixing boards, the studio fader has the advantage of a low noise level. This means that the motion of the potentiometer won't interfere with your listening pleasure.

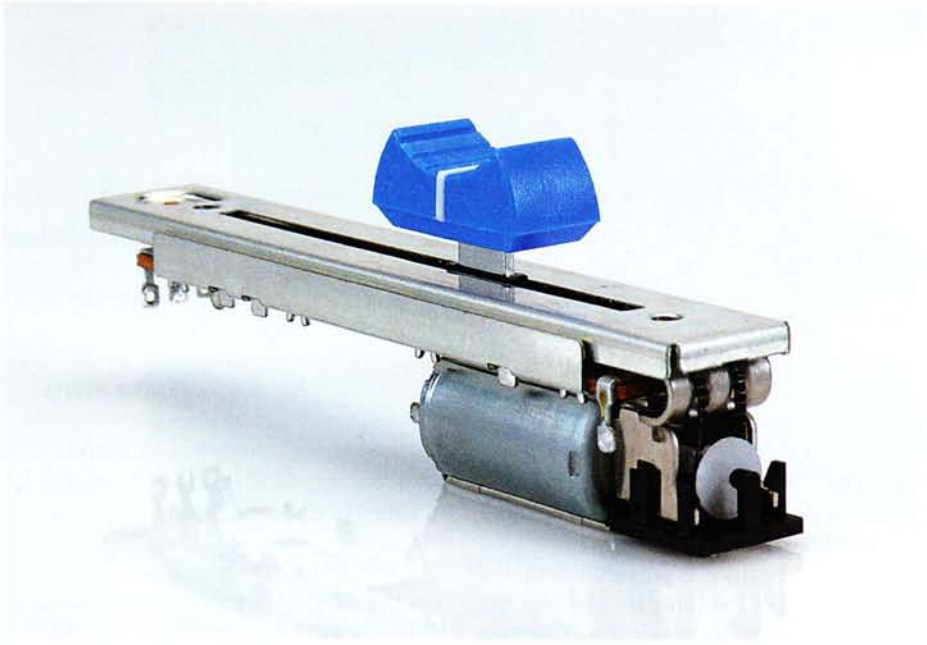


Figure 1. An Alps studio fader is used as a combined indicator and entry device.

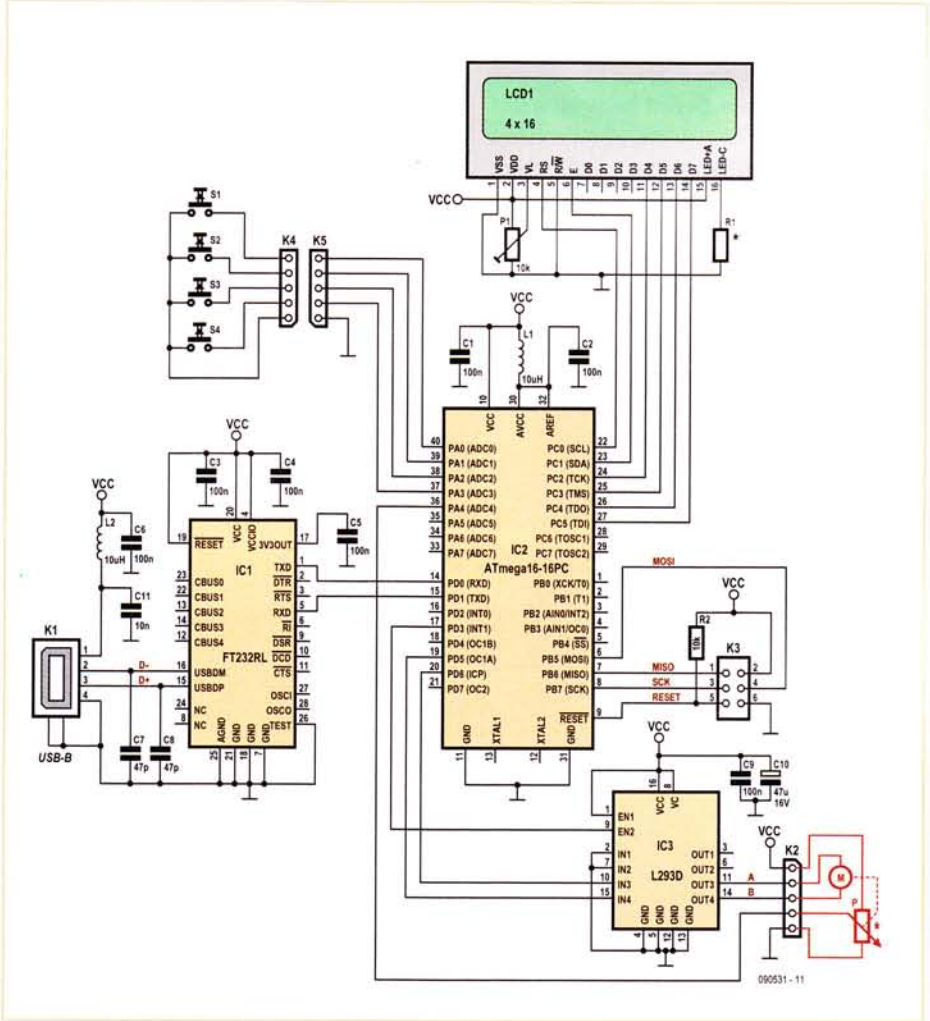


Figure 2. Schematic diagram of the Winamp controller, which the PC sees as a USB device.

AVR firmware

As already mentioned, the software for the AVR microcontroller has been developed

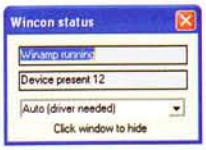


Figure 3. The Visual Basic program Wincon links the external hardware to the Winamp API via USB.

with BASCOM. In normal operation, the software compares the value received via the serial interface with the current position of the slider. If these values differ, the slider position is adjusted accordingly.
If one of the buttons is pressed or manual repositioning of the slider is detected, the AVR microcontroller sends the PC a data byte with the new position.

Manual repositioning is recognised based on various trigger conditions:

- The slider value changes while the motor is not energised
- The slider value changes while the motor is energised, but in the wrong direction
- The slider value changes while the motor is energised, but at the wrong speed (the slider is blocked)

Windows software

On the PC side, a small Visual Basic program connects the external hardware to the Winamp API (with the aid of the USB interface). It is not necessary to configure a Com port setting, since the function *Ft_getport()* can determine which serial port is being emulated (**Figure 3**). If the device is

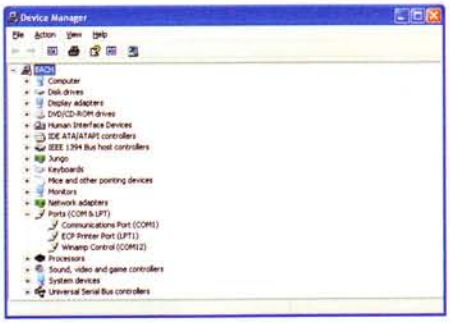


Figure 4. The Winamp controller in Windows Device Manager. The FT232RL designators are programmed to allow the Winamp controller to be recognised as a USB device.

COMPONENT LIST

Resistors
R1 = see text
R2 = 10kΩ
P1 = 10kΩ preset
P2 = mixing desk fader with motor, Alps type RSA0N11M9 (10kΩ) or RS60N11M9 (5kΩ); see text

Capacitors
C1,C2,C3,C4,C5,C6,C9 = 100nF
C7,C8 = 47pF
C10 = 47µF 16V radial

Inductors
L1,L2 = 10µH axial choke, e.g. Bourns JW Miller 5300-13-RC

Semiconductors
IC1 = FT232RL (FTDI)
IC2 = ATmega16-16PU (Atmel), programmed
IC3 = L293D (ST) or L293DNEE4 (TI)

Miscellaneous
K1 = USB socket, type B, PCB mount
K2,K4,K5 = 5-way SIL pinheader, 2.54mm lead pitch
K3 = 6-way DIL pinheader, 2.54mm lead pitch
S1–S4 = pushbutton, 6mm footprint; PCB mount, e.g. Multicomp MCDTS6-5N
LCD1 = LCD module, 2x16 characters, e.g. Displaytech 162C
PCB # 090531-1
Project software, file # 090531-11 from [5]
Kit of parts including PCB, item # 090531-71 from the Elektor Shop or [5]

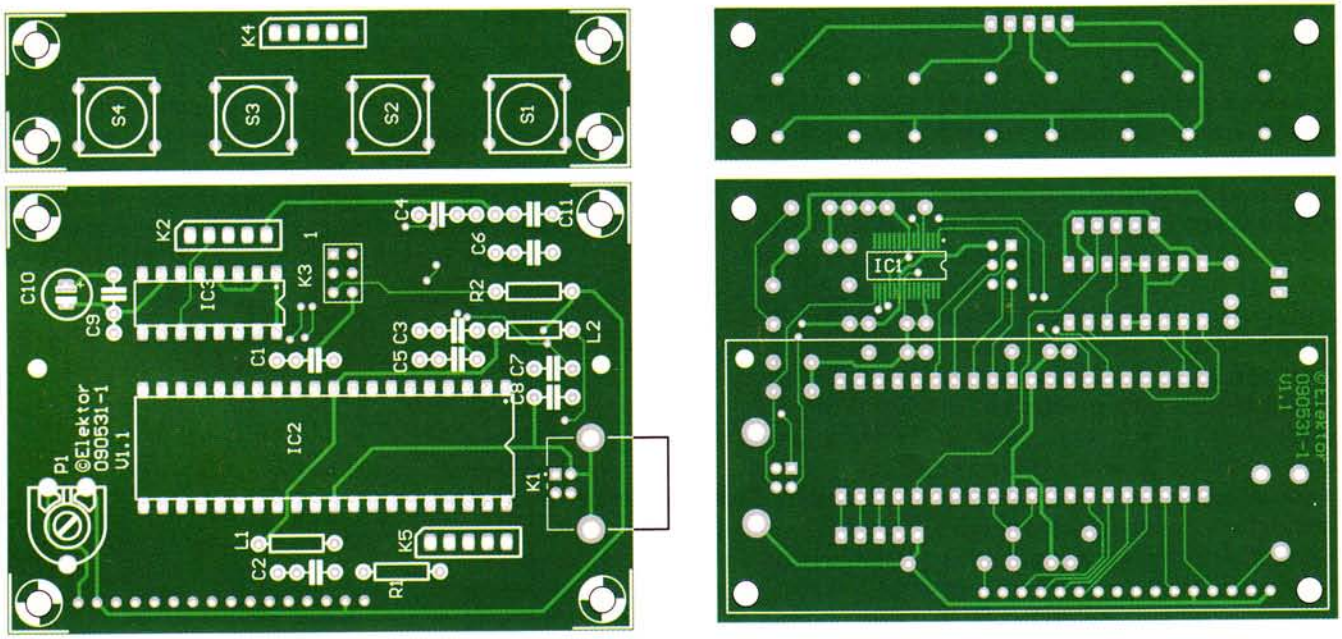


Figure 5. The Elektor lab prototype of the Winamp controller.

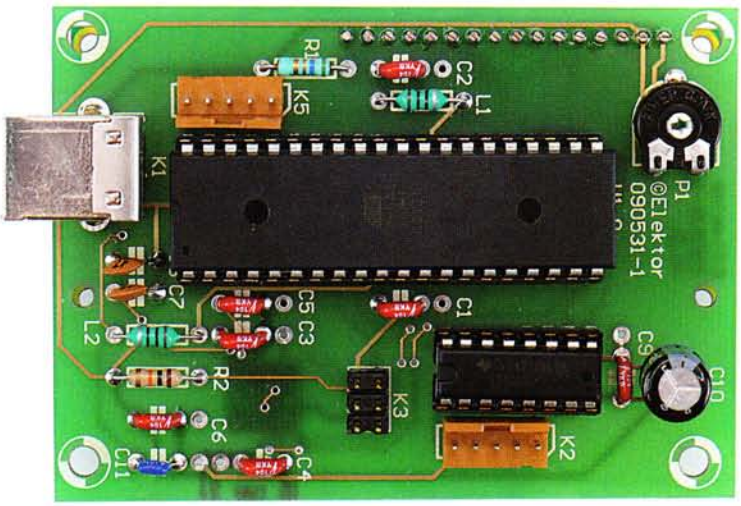


Figure 6. The fully assembled lab prototype PCB.

not connected, no connection is found and an error message is displayed.
The program has to perform only three simple tasks, which allows it to be very compact and tidy:
1. The current position of the virtual progress bar in Winamp is sent to the hardware every second.
2. If the external hardware reports that the fader has been repositioned manually, the software executes a 'fast forward' or 'fast reverse' to the corresponding position in the song.
3. If a new song is played, its title is sent to the hardware in 32-bit format.

If Winamp is not running, an error message is displayed or the icon in the system tray turns red.
The software can be modified or extended using the free Visual Basic Express development environment [3]. For example, you could change the functions of the control buttons.
When one of the four buttons is pressed, a value in the range of 251 to 254 is sent. The value range from 0 to 200 is reserved for the slider position.

FT232RL programming

The benefits have already been mentioned briefly: if the descriptors of the FT232RL are programmed properly, Windows programs (such as programs generated in Visual Basic) can recognise the USB device and independently detect the associated Com port (**Figure 4**).
This requires changing the product description of the FT232RL into 'Wincon'. The drivers for the USB-to-serial converter are usually available on the Windows system, so no installation will be required. The PID and VID however have to remain at the original FTDI value. The free FTProg program from FTDI [4] is used here for programming. This program is well documented. A XML file available on the Elektor website [5] for free downloading is used for device programming. If you want to make do without this step you may select a COM port manually in the VB program. The source code of this program is also included in the downloadable Zip file.
If it is desired to retrofit the automatic COM port function to your own project, all you have to do is change the product name into 'FT232L' and convey the relevant string as a parameter to the FT-getport() function.

Practical aspects

A printed circuit board (**Figure 5**) has been developed for assembling this circuit. It consists of two parts: a microcontroller board and a keypad board with four buttons, which can be separated from the microcontroller board. Assembly is straightforward, with the exception of the FT232RL (IC1). It is the only SMD component in the circuit, and it is fitted on the underside of the board. With a bit of practice, the SSOP-28 package (lead pitch 0.65 mm) can be soldered reasonably well by hand.
The LCD module is also fitted on the underside of the board. It can be plugged in using pin and socket headers (see **Figure 6**). The value of R1 should be chosen according to the LCD module that is used. If a module

Advertisement



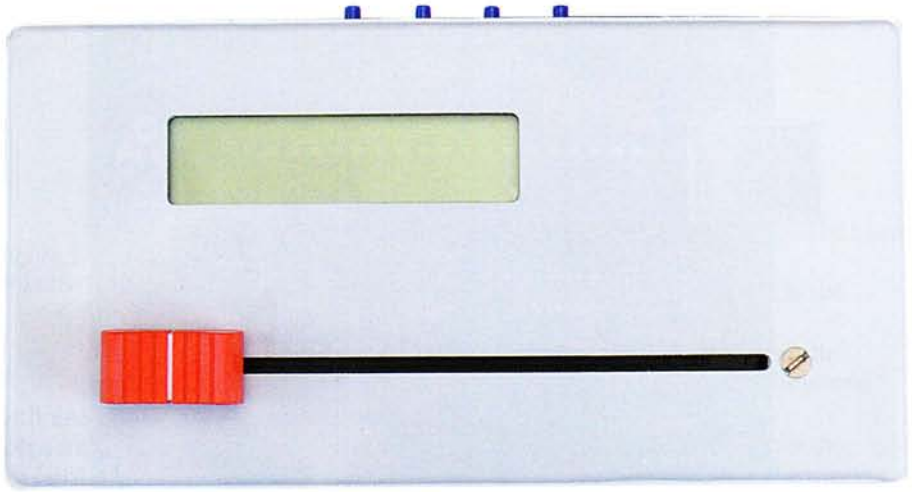


Figure 7. The author's prototype.

without backlighting is used, pins 15 and 16 of the LCD module are not used and R1 can be omitted. The prototype was built using a module with a green backlight, with pin 15 connected to the anodes of the backlight LEDs and pin 16 connected to the cathodes. In the circuit diagram (Figure 2), pin 15 is connected to +5 V and pin 16 is connected to ground by R1. The voltage across the LEDs (U_F) is specified in the LCD data sheet as 4.2 V, with a typical LED current of 160 mA. This yields the following value for R1:

(5 V – 4.2 V) / 0.16 A = 5 Ω

We used a value of 5.6 Ω in our lab prototype. If you use a display module with a different type of backlight, you should adjust the value to match the LED current recommended by the manufacturer. For example, a model with a visually more attractive but more expensive blue-white backlight has a much lower LED current (around 15 to 40 mA).
The microcontroller can be programmed in circuit using a suitable programmer, such as Elektor USB AVRprog or AVRISP Mark II, via the ISP port on the PCB (connector K3). The kit of parts on sale fort this project contains a ready-programmed microcontroller.
The author used a readily obtainable Alps studio fader for the motorised potentiometer. Two versions are available from catalogue distributors such as Mouser, Reichelt and Conrad Electronics: one with a 5-kΩ potentiometer and 60 mm slider travel, and another (slightly more expensive) with a 10-kΩ potentiometer and 100 mm slider travel. The author used the latter version in his prototype (**Figure 7**), while the smaller 5-kΩ version can be seen in the photos of the Elektor lab prototype. Both versions can be used, although we recommend the 10-kΩ version due to its longer slider travel.
The only wiring that is required is to connect the studio fader and the keypad PCB to the microcontroller PCB. The slider potentiometer is shown in the schematic diagram with its leads connected to pin 1 (+5 V), pin 4 (slider) and pin 5 of K2, while the motor leads are connected to pins 2 and 3 of K2. If the slider motion matches the progress bar on the monitor after the unit is put into service, the polarity of the motor lead connections is correct. Otherwise (or if the slider does not move) the motor leads must be reversed.
The prototype can be admired in action in a video clip [5] produced by the author.
In normal operation, with the device connected and Winamp playing an MP3 file, the PC sends the current progress bar position to the device and the slider is continuously moved to the corresponding position. When the song ends, the slider returns to its initial starting point.
If you use the mouse to change the position of the virtual Winamp slider while a song is playing, the slider of the fader also moves to the corresponding position.
Thanks to the dual operating mode, the studio slider in the circuit can also be used as an input device. If the slider is moved manually, the motion is detected by the AVR microcontroller and motor-driven operation is stopped immediately. If after this the slider remains in the same position for a certain length of time, its position is sent to the PC and the Windows program moves to the corresponding position in the tune. The four buttons can be used to change to the previous or next song or to trigger the Winamp Play and Stop functions. The song title is shown on the LCD module in two lines of sixteen characters each. If you don't see anything on the display, it may be necessary adjust the display contrast with trimpot P1.

090531-I

Internet Links

[1] www.winamp.com (Winamp)

[2] www.mcselec.com (BASCOM AVR)

[3] www.microsoft.com/express/vb/Default.aspx (Visual Basic Express)

[4] www.ftdichip.com (FT232RL driver documentation and programming tool)

[5] www.elektor.com/090531 (Elektor project web page)

[6] www.diamantic.com/projects/electronics/021 (author's Winamp controller demo video)

About the author

Markus Hirsch was born in Hanover in 1978 and grew up in Vienna. During his course of study in precision mechanics at the University of Hanover, he discovered his passion for digital electronics — even though this had little in common with his main course of study. After working several years in a medium-sized industrial firm (ultimately in a quality assurance position), Markus completed a course of study in electrical engineering at a technical college. He now enjoys combining his two fields of knowledge.

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Website: www.diamantic.com

Motorbike Chain Oiler with PIC

By Esko Viiru (Finland)

Problem #1: rainy day, 200 miles to go, chain lube spray / forgotten / empty / under loads of baggage. Problem #2: Touring with buddies who have shaft driven bikes. Take a break and think it's a good time to oil the chain. "What the #^% are you doing? Got a problem with your bike?" That's enough! Something must be done. Bulky shaft driven bike? No thanks. Belt driven? Phew! How about an automatic chain oiler?

Problem #2a: where's a cheap and reliable oil dispensing device, please? The author is grateful to MC Jäykät from Finland [1] for the idea to use a low-geared windscreen washer pump as the oil dispenser.

A visit to the local equivalent of *Die Ludolfs* [2] resulted in a spring loaded non-return valve and some windscreen washer tubing. Main problem solved, the rest of project will be 'just electronics and software'. Not quite. Real motors have internal resistance (R_s) and electromotive force (E_m) that's directly proportional to the rotation speed. If you want to accurately measure a fluid volume through electromagnetic force, the voltage drop due to the motor's internal resistance is effectively cancelled:

$$E_m = U_m - R_s \times I_m$$

To keep things simple, let's ignore the motor's inductance. To justify this simplification, the motor is powered by a constant current source. Some analogue circuitry will be needed — can't be helped.

The electronic design

The circuit of which the schematic is shown in **Figure 1** and the wiring diagram in **Figure 2** gets its supply voltage from the bike's

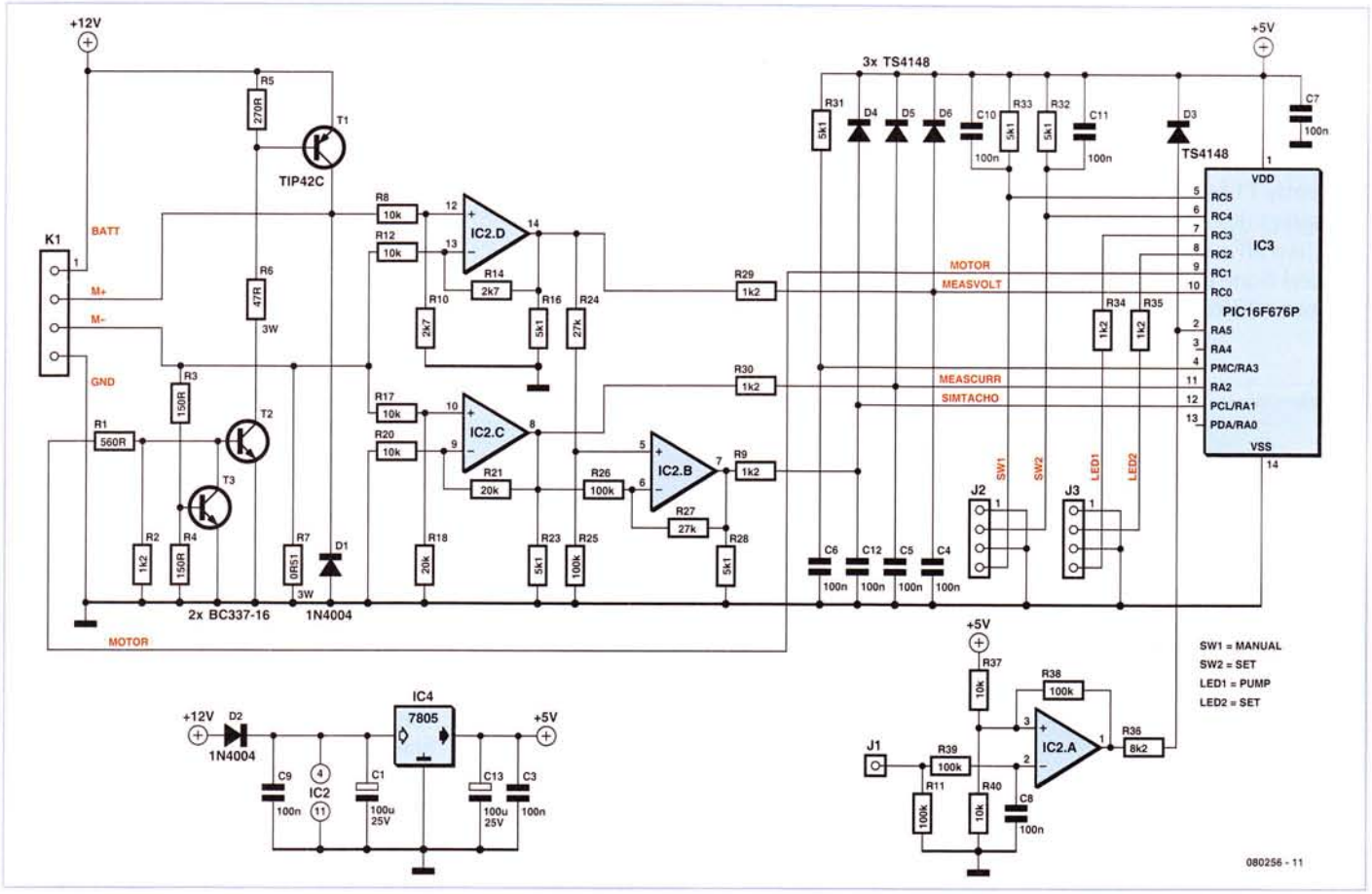


Figure 1. Circuit diagram of the motorbike chain oiler with intelligent oil dispensing.

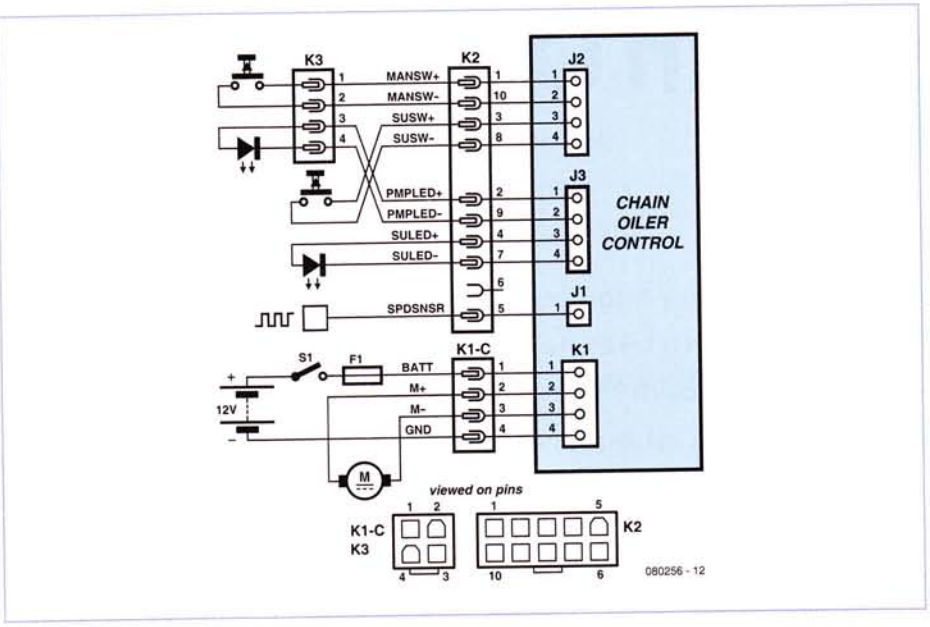


Figure 2. How to connect the unit to various signals and wires on the bike (example: Suzuki SV650S).

battery via the ignition switch and a fuse (5 A). Power for the windscreen washer pump is switched by power transistor T1 which gets its control from a PIC microcontroller via driver T2. The return current from the motor is passed through current measuring resistor R7. When the motor current reaches its high limit, transistor T3 starts to conduct and 'steals' base current from transistor T2. This results in T2 and consequently T1 being cut off. Negative voltage spikes due to the motor coil(s) being switched off suddenly are shunted off by flywheel diode D1.

The motor voltage is measured by op amp IC2D which is connected as a differential amplifier. The amplification factor of 0.27 scales the motor voltage (max. ~14 V) down to the PIC's safe measuring range (max. 5 V). The motor current is sensed by R7. Differential amplifier IC2.C then amplifies the sense voltage by 2, resulting in a total amplification of 1 V/A.

The 'simulated tachometer signal' for the motor speed measurement is realized by subtracting the (calculated) voltage drop due to the motor's internal resistance (R_s) from the total motor voltage. This is done by IC2.B which is connected as an asymmetrical differential amplifier. The amplification for the non-inverting input (i.e. motor voltage) is unity (1). The total amplification for the motor voltage is thus: 0.27 × 1 = 0.27. The pump motor used was found to have an R_s of 1.0 Ω. So, the voltage drop due to the R_s is 1 V/A which happens to be the same 'slope' as that of current measuring op amp IC2.C. Because the motor voltage is scaled down by 0.27, the voltage across R_s must also be scaled by the same factor 0.27. Thus, the amplification for the inverting input is 0.27.

Referring to the labels in the circuit diagram we have:

MEASVOLT = 0.27 × motor voltage

MEASCURR = 1 V/A × motor current

SIMTACHO = 0.27 × (motor voltage – 1 V/A × motor current); ([Ω] = [V/A])

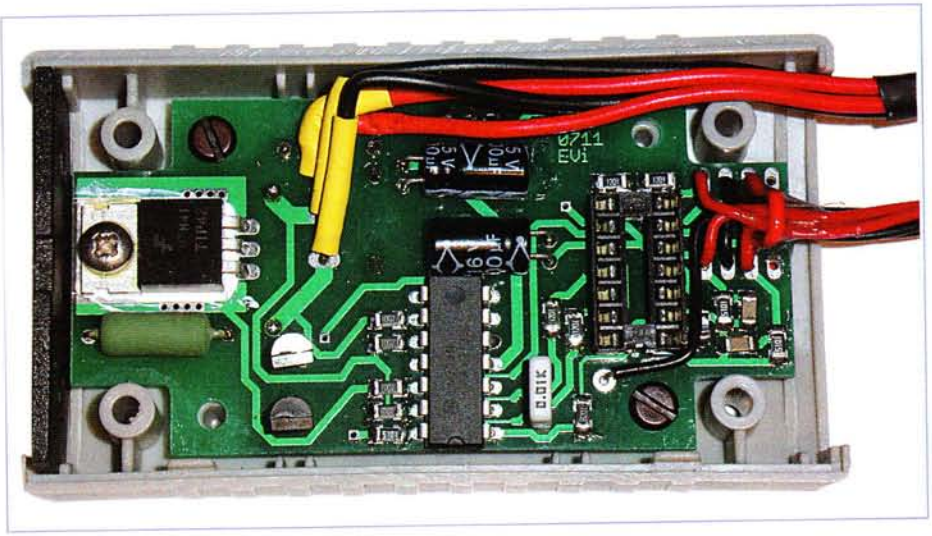


Figure 3. The board is double-sided and has a mix of SMD and through-hole components.

The measured signals are connected to the PIC's (analogue) inputs via low pass filters. Diodes D4, D5 and D6 clamp excessive input voltages to safe levels.

The type LM224 op amp is used because the common mode range of its inputs reaches GND and the output can go down to GND as well. However, the sink current of the LM224 is very small when the output is near GND, so pull-down resistors are connected to the outputs.

The digital part is quite straightforward. Pulses from the speed sensor on the bike are connected to IC2.A but noise spikes are filtered out first. IC2.A's input impedance is high (100 kΩ) to prevent excessive loading of the speedometer electronics. The op amp is configured as a Schmitt trigger and its output is taken to a PIC digital input via resistor. Diode D3 clamps the input voltage to the safe level. The Schmitt trigger and the low pass filter are designed based on the speedometer signal present on a Suzuki DL/SV650.

Both switch inputs on J2 have pull-up resistors with small capacitors connected in parallel to eliminate noise spikes.

The PIC16F676P is configured to use its internal 4 MHz oscillator so a dedicated crystal is not needed.

There are two supply rails: +12 V and +5 V. The +12 V is taken from the bike battery

through diode D2 and it powers op amp IC2 as well as voltage regulator IC4. The regulator is the ubiquitous 7805 and it powers the rest of the control electronics.

Software

An assembly code program was developed under Linux using these 'gputils' (tools): gpasm, (assembler/compiler) and gplink (linker) [3]. For Windows there is a free (assembler) development environment available from Microchip called MPLAB IDE.
The final firmware is transferred to the PIC micro using the 'Tait' classic programmer and ICprog software under Windows XP. ICprog requires that the NT/2000/XPparallel port driver be installed on the system. A more contemporary alternative to use is the Microchip PICKit 2 or one of its clones.

The program has the following functions:
- Rain / Dry setting at start up.
- Manual start of oiling sequence.
- Automatic lubricating with two adjustable parameters: (1) travelled distance between oiling sequences and (2) pump 'on' time during oiling sequences.

The commented source code as well as the HEXcode files are available free from the Elektor website [4].

Construction hints and operation

Because space is at a premium in a modern motorbike, it is suggested to build the circuit on a double-sided PCB populated with SMD as well as through hole components. The author's PCB design may be downloaded from [4]; Eagle and Gerber formats are supplied. Soldering should not be a problem because no extremely small or multi-pad SMD components have been used. The PIC microcontroller should be mounted in a high quality IC socket. Diode D2 is placed between connector pads and it might be good idea to leave some clearance between it and the PCB surface. **Figure 3** gives an impression of the finished board.
The PCB is designed to fit into a Kemo type G111 plastic case with dimensions 90x50x25 mm. Due to the limited space (mainly height) inside the case, the connection wires are soldered directly to the PCB.

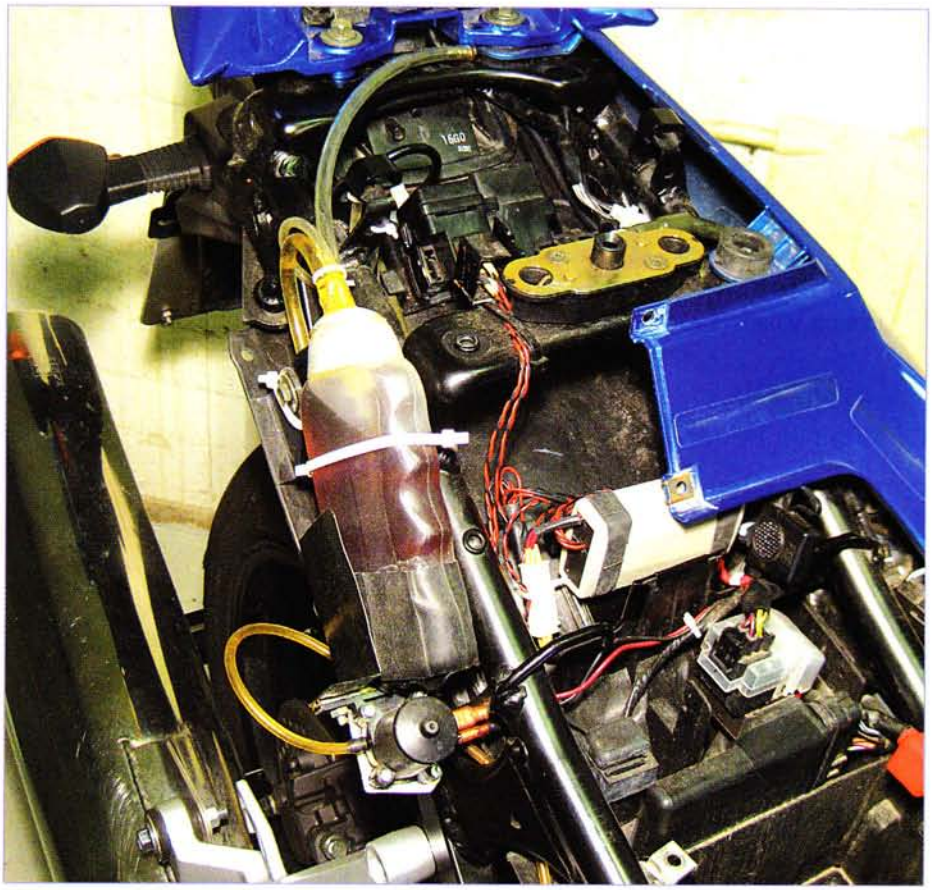


Figure 4. Suggested mounting of control circuit, pump and oil 'tank' on a Suzuki SV650S motorbike.

Wire-to-wire connectors are used outside the case.
Finally, the operation of the unit by means of the two pushbuttons is described in a document called *080256-W.pdf* included in the project download at [4].

(080256)

Internet Links

[1] www.24.fi/mcjaykat
[2] http://press.discovery.com/emea/dsc/programs/die-ludolfs/
[3] http://gputils.sourceforge.net/
[4] www.elektor.com/080256



Figure 4. Rather than dripping oil on the chain and spilling most of it while riding, the dispenser lubricates the rim of the chain wheel.

Femto OS

A tiny multitasking operating system for microcontrollers

By Clemens Valens (Elektor France Editorial) and Jerry Jacobs (Elektor Labs)

Do small embedded systems need a multitasking operating system? Can't you just program everything in one big loop? Sure. But have you ever noticed the wait between switching on your DVD player and the first signs of the drive responding to the Play button? We bet that there is no OS inside, just a big loop. It is easy to do better since there exists an OS for even the smallest of microcontrollers.



The next question is: do you have to write one yourself? On Wikipedia [1] almost one hundred are listed already, but ignoring the proprietary systems and those that are not under active development, the list is actually much shorter. Probably the only one that will fit into 8 KB of flash memory and 512 bytes of RAM and still do something useful is Femto OS [2]. It was written by Dr R. Vlaming MSc. to be a general-purpose OS, useful in many different applications. The word 'femto' (10^{-15}) in Femto OS indicates that the OS is very small indeed.

Goals

Femto OS is a multitasking real time operating system (RTOS) with a fairly generic design. It is portable and currently ported to 44 of Atmel's AVR microcontrollers. It is open source and licensed under GPLv3. Femto OS differs in several respects from other operating systems. First of all Femto OS is extremely economical with RAM and flash memory. Only the things you really need get compiled into the kernel. For example, you can run eight independent LED blinking tasks within 1 KB of flash and just 47 bytes of RAM. Or you can run a shell, serial communications (so you can log into the device) and eight other tasks on an ATtiny861 (8 KB flash, 512 bytes RAM). We sincerely believe that Femto OS is the smallest OS on the planet. The code is well documented too.

Why use a multitasking OS?

Often, when a microcontroller is performing a task, it waits in an infinite loop until something happens — a button press for example, before it will do something like switching on or off a light. In pseudo code:

```
forever do
{
  wait for yellow button to be pressed;
  invert yellow light state;
}
```

Now suppose you have two buttons and two lights. The following program does not work well (can you see why?):

```
forever do
{
  wait for yellow button to be pressed;
  invert yellow light state;
  wait for blue button to be pressed;
  invert blue light state;
}
```

so we have to do something like

```
forever do
{
  wait for yellow or blue button to be pressed;
  if button was yellow then invert yellow light
state;
  if button was blue then invert blue light
state;
}
```

But wouldn't it be much simpler if we could use two loops that

Getting started with Femto OS

There are two ways of getting started with Femto OS: the easy way and the hard way. Both ways start with downloading the Femto OS distribution from the Femto OS web site [2]. In the archive file for this article you will find a readme file. Read it, it's highly detailed and contains lots of useful information.

The easy way is to use Femto OS with AVR Studio [6] and WinAVR [7], but this only works with Windows. You have to download and install these two programs and then run the install_avrstudio_workspace.bat file that's included in the Femto OS distribution. That's it, you're done! Our example is presented as an AVR studio project and you could copy it into the IDE/studioprojects folder of the OS distribution.

The hard way, for those who like to know everything, is also detailed in the readme file. The hard way works on Windows, Linux and Mac. It involves setting up your own Femto OS tool chain, building everything (yes, everything, the compiler too) from scratch. In our experience this is only for the real geeks and it never works, but we gave it a try anyway. So we did install Cygwin (this was on a Windows Vista machine), downloaded the special packages, ran the configuration scripts, built the whole kit and caboodle and what say: no errors! OK, it took five hours and 200 MB but then we were able to compile a 258 byte program! To be honest, we did run in an annoying Windows Vista security problem: we (administrators) were not allowed to access the Femto OS source files... Using the file properties the security settings were changed to get 'total control' and then it worked. To discover this it's necessary to inspect the compile_results file in the MainCode\binaries\ folder of the Femto OS distribution. Alternatively, take the easy way...

would be executed in parallel? Like this:

```
forever do
{
  wait for yellow button to be pressed;
  invert yellow light state;
}

forever do
{
  wait for blue button to be pressed;
  invert blue light state;
}
```

This is the premise of the multitasking OS —you can have one or more 'tasks' that are executed simultaneously, allowing you to reduce program complexity.

A typical multitasking OS design

Figure 1 shows the flowchart of a typical multitasking OS. After some system initialisation (the timers of the AVR for example) the scheduler takes over. The scheduler keeps a list of all tasks and selects one of the tasks to run. Which task has to be started next will depends on its priority (more important tasks go first!) and, with priorities being equal, which tasks did not yet run. This is called **round robin**. Once a task has been selected the context for that task is restored, and execution resumes at the point where the task was halted earlier on.

What does that mean 'the context is restored'? Program execution is no more than bit manipulation of the registers of the CPU and the memory. When a program resumes execution after being interrupted, at least the registers it was working with should contain the same values as before the interruption. So a 'context save' makes sure that the regular working registers of the CPU — the Status Register and Program Counter — are saved in a special area of memory

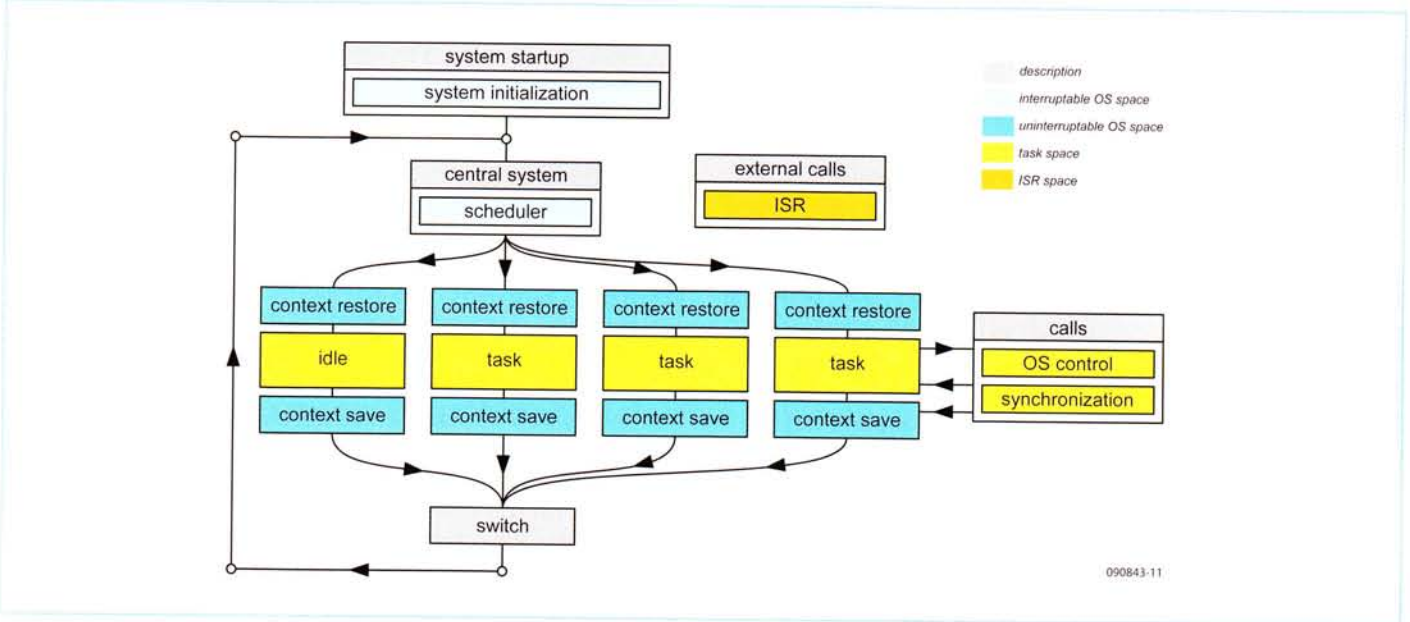


Figure 1. The flow chart of a basic operating system.

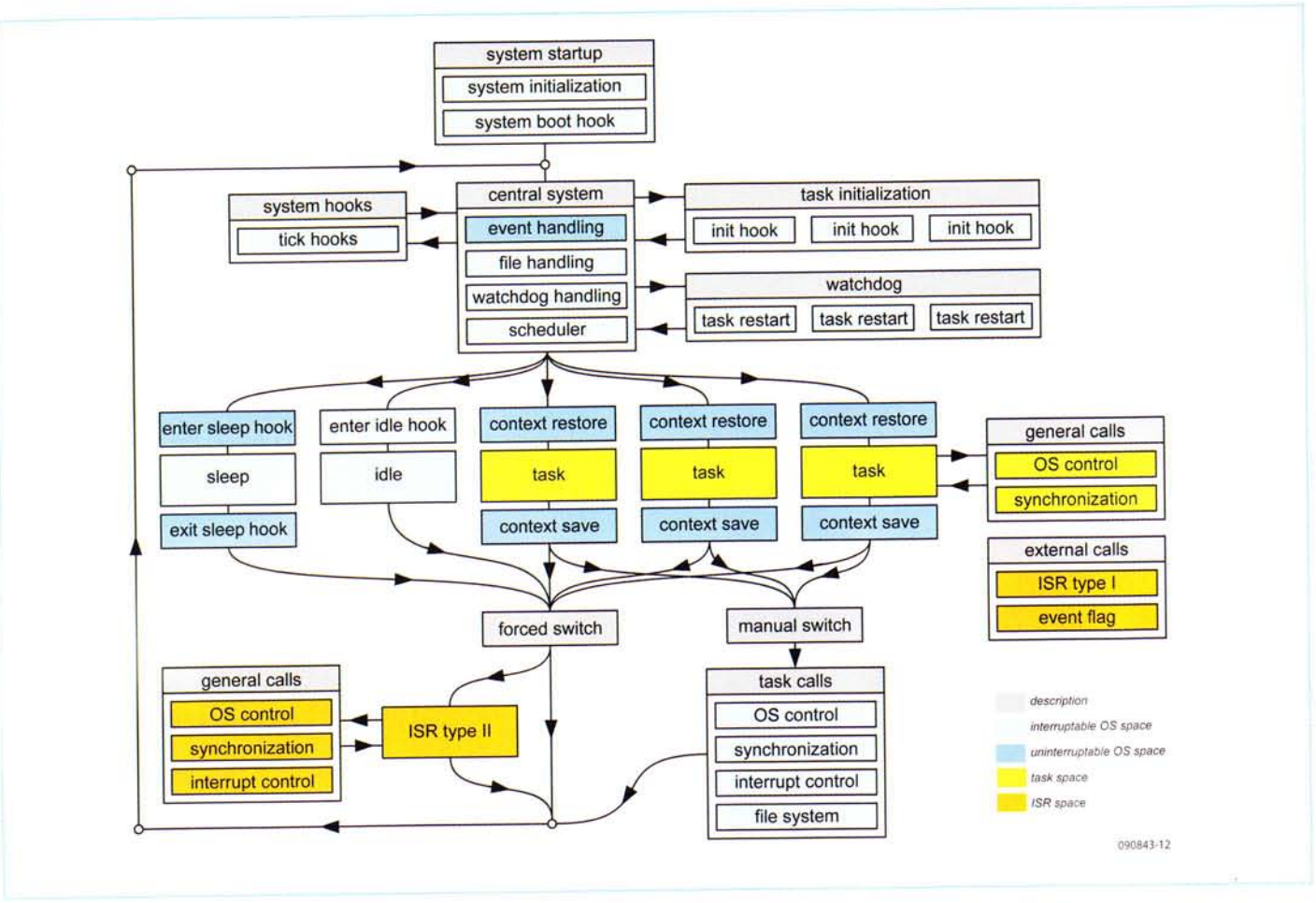


Figure 2. The flow chart of Femto OS is a bit more complicated than the one in Figure 1, but not that much.

where the program stores return addresses and temporary variables: the **stack**. The stack pointer itself must be saved at some fixed location. Just before the end of the interruption, the register values are read back from the stack and written to their original locations. This is a context restore. If the context save and restore are done properly, a program never notices that it was interrupted.

When a task has run for a while, the OS takes control again by interrupting it, usually by means of a timer interrupt, the so called *tick interrupt*. Immediately after the interruption, the context of the task is saved and its state is frozen. We have now reached the block named switch in **Figure 1**. The process is called **pre-emption** because the task cannot refuse this interruption. The task control block (the memory that holds all the information about a task) is updated, and the scheduler selects a new task for execution. If there are no tasks ready to run — they may all be waiting for something — the scheduler selects the idle task, which does nothing.

It can happen that a task wants to call a function that controls the OS, or a task may want to communicate with another task, so it might call some synchronisation functions. In such cases the task no longer needs to run and it may dedicate the execution time left to other tasks. The task switch is now voluntarily (so-called **cooperative** operating systems work solely on this basis).

As discussed, the context save and restore ensure that the environment of the task that's allowed to run is identical to its environment when it was switched out. But what about the rest of the memory? Or indeed the registers of the peripherals? For the most part, it doesn't really matter since the task never uses it. And for the part the task is using, it will often be the only one using it, so this part will not be touched when the task is not active. What remains are the registers in use by more than one task. How is this organised? Well, it isn't. It is your responsibility. Of course the OS offers some synchronisation tools and semaphores to make life a bit easier, but you, the application builder, have to be careful. If you aren't, tasks may deadlock forever.

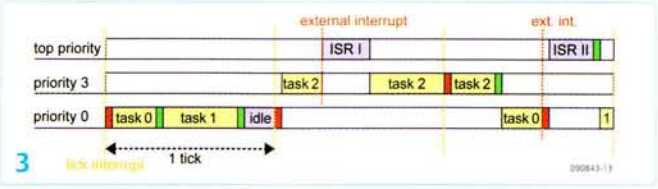
This is about all there is to the design of a clock driven pre-emptive multitasking operating system. Of course, there are all kinds of other exotic designs out there, but for the discussion about Femto OS this backdrop will be sufficient.

Femto OS features

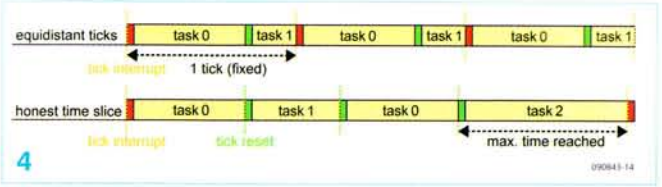
In **Figure 2** you will recognise the generic OS design from Figure 1 but also notice many new blocks. First of all, we have a system initialisation with a global boot hook and every task has an initialisation hook, which are places where you can add custom functions to initialise, for example, hardware before your tasks start. These are one-time initialisations.

The block 'central system' contains a few more gadgets. Event handling takes care of possible events that you may have initiated. These are used to quickly fire up a task from an interrupt or other task. Subsequently, file handling unblocks possible tasks that were waiting for an EEPROM write operation to end. A watchdog tests for tasks that are no longer responding and that may need to be

Timing models



3



4

Figure 3 shows an example of how tasks execution evolves over time. The horizontal axis represents time, the vertical task priority. This snapshot of the system starts with a forced context switch (red rectangle), followed by execution of task 0. After a while this task transfers execution to the OS; a manual context switch takes place (green rectangle) followed by the execution of task 1. If it also happens that task 1 does not need the full time, it requests a manual context switch again and the rest of the tick time left is spent in the idle state. In the mean time task 2 has woken, and since this one has a higher priority, it takes precedence.

During execution of task 2 an interrupt takes place which is handled immediately. After completion of the ISR, task 2 continues until it gets interrupted by the tick interrupt. Unfortunately, task 2 hadn't finished yet, but since it has the highest priority it is rescheduled. When done it yields control to the OS who reschedules task 0.

Then an interrupt arrives that forces a context switch before starting the ISR. When the ISR completes no context needs to be saved, but the context of task 1 must be restored. Note that, although task 0 has not yet finished, task 1 is scheduled anyway. This is because the OS has no way of knowing if a task has finished or not, so it assumes it is.

Normally, ticks come at equidistant time intervals, which is fine for most situations, but not for all. To illustrate this, have a look at **Figure 4**. In the upper time line you see two tasks running. Since task 0 uses most of the time between the ticks (but not all of it) there is little time for task 1 left. But, because it did run, the OS will restart task 0 after the tick interrupt. This goes on and on and may lead to starvation of task 1. In extreme cases it may even execute a few instructions only. Although such situations are rare, the do occur and can be hard to track down.

Femto OS lets you use another timing model, called **honest timing**. In this case, at program start the tick interrupt timer is reset so every task gets a full tick time to run. If the task completes before the next tick arrives, the timer is reset for the next task. The tick counter keeps on counting regular ticks (for these are deduced from the sub tick counter) although it may lag a little. Observe that in this model task 1 does not starve. In fact, this allows another possibility: variable time slices per task where each task has its own maximal time slice. This can be very handy if you know beforehand that a particular task needs a little more time than one tick to complete and it may reduce context switch overload considerably.

restarted. This is a useful option for checking if a communication bus is still busy and removes the need for countless timeout checks throughout the program. And lastly the scheduler selects a task following the simple prioritised round robin scheme.

Besides starting a normal task, the system can go into idle mode, which is not a task but simply a power saved state in OS space. The system can also go to sleep (if supported by the hardware). This is a special power down mode of the chip that includes the tick interrupt.

Just as in the generic OS, tasks can be interrupted by the tick interrupt or by a manual switch. But in contrast with the generic OS, the Femto OS control calls take place in OS space for most functions, hence force a manual switch first, after which the operation is executed. This way the task stack is not used for these operations, and thus the task stack size can be smaller. In Femto OS most calls that directly force a context switch are called taskXXX and may only be used from within a task. In addition to that, there are also general calls, starting with genXXX that may be called from within tasks as well as from interrupt service routines. They do not force a context switch and are executed in the same space as the one they where called from and are usually very quick.

Femto OS provides everything you need for safe inter-task communication. This is important when two (or more) tasks need to share data or access the same register. **Mutexes**, **queues** and **rendezvous** are therefore fully supported. We do not have enough space here to dig deep into these advanced concepts, but as a potential Femto OS user it is good to know that the tools to handle this properly are available.

Controlling relays...

It is all very well to know how an OS works in theory and how useful it is etc., but we are hands-on people and we want to play with it. Nothing beats a real-life example to illustrate how things work in practice. Elektor has published many AVR-based boards so we decided to reuse one of these. We went for the ATM18 board [3] to try Femto OS on. To make it more interesting we also added the I/O port expander (071035-5) with the relay extension card (071035-6) [4].

The ATM18 board sports an Atmel AVR ATmega88 microcontroller with 8 KB program flash and 1024 bytes SRAM memory. Because Femto OS has a very small memory footprint there is enough memory for a pretty big application with multiple tasks. We prepared a simple application that nicely illustrates how three tasks can make a programmer's life much easier. Of course you can download the source code from our web site [5].

...using multitasking

The first task is a data output task. It writes data to the shift register of the port expander board over a synchronous bus. The port expander controls eight relays. This kind of communication is a good target for a task. The application only has to send data to the task and the task will make sure that the bits and bytes are transmit-

Why would I want an OS on my microcontroller?

Most people do not understand why you would want an operating system on a microcontroller, yet everybody wants one on his PC. The first PC with its 8088 5 MIPS max processor wasn't a lot more powerful than a modern small microcontroller but yet we all wanted a DOS (disk operating system) on it. And these early operating systems weren't even multitasking.

The reason for this is probably that most people think of Windows, Linux or Mac when they hear 'OS' and how would you squeeze *that* in an 8-bit microcontroller? Within the context of Femto OS, these big operating systems look just like an Airbus A380 compared to small remote controlled indoor helicopters. Yet they both fly.

An operating system is useful when you have many peripherals, and modern microcontrollers come loaded with these. The operating system takes care of many low-level tasks to control the peripherals and makes life of the application programmer easier. That's why you want an OS, to relieve you from the tedious tasks of handling time-outs everywhere, to do the bit-banging for you, to process interrupts properly. If you use an easily portable OS, you can run your application on many different processors without modifications. Reuse your code and save time and money, just by using an OS.

ted in the right way. While the task is doing just that, the application can do something else.
A second task reads the state of the five switches that live on the ATM18 base board. The switches connected to port lines PD0-3 control the relays and the switch connected to PD4 selects between the two rows of four relays (RE1-4 and RE5-8) on the relay card. The switches are connected to 0 V and have an internal pull-up set on the port, so they are read as 'zero' when they are pressed.
Finally a third task provides some visual feedback by controlling two LEDs to show which row of relays is selected. If LED1 lights up the relays RE1 to RE4 are selected, else LED2 lights up indicating that the relays RE5 to RE8 are selected. The LEDs are connected to PB0 and PB1.
If you look at the application file, the one with 'Elektor' in its name, you will find only a few functions and no 'main' (the main can be found in "femtoos_core.c"). So how does this work? With Femto OS you have to decide at compile time how many tasks you intend to run. That's how the OS can be so small. A special configuration file is used to tell the compiler what parts of the OS it should include and which functions are the actual tasks. If you want to understand in detail how the configuration process works, you are in for a long voyage through pre-processor land. For a quick start it is easier to just use the example configuration file "config_application.h" and change the parameters you need (only change the ones you understand).
Under the header "TASK NAMES" you define the names of your tasks (Display, Speed and Switch in our example). Then, under the header "INCLUDE TASKS" you tell the compiler which tasks should run. In the application file you should provide a function for each task with a name that starts with "appLoop_" followed by the name of the task (appLoop_Switch, appLoop_Speed & appLoop_Display in our example). If you do this correctly the Femto OS core will call your tasks at runtime. You now have sort of as many main functions as that you defined tasks (up to 16).

This example only shows a small piece of the many capabilities of Femto OS. In the OS distribution available at [2] you can find several other examples that you could try on the ATM18 board.
Refer to the *Getting Started* document supplied with the Femto OS frame to learn how to, well, get started! Once you are up and running, you can try our example.

Nice, but I am not convinced

After reading about our example some of you will remark that they can do the same thing using interrupts and loops etc. You are right; you do not have to use an OS. But take a good look at our example and notice how simple it really is. We only wrote the file that has 'Elektor' in its name and configured some settings. If you were to write this application using interrupts or polling you can look forward to spending a lot of time testing and figuring out how to get it working properly. You can save this time (and several headaches) by letting the OS handle it for you. Let other people do the hard work for you while you are having a beer.

(090843-I)

Links and references

[1] http://en.wikipedia.org/wiki/List_of_real-time_operating_systems
[2] http://femtoos.org,
this text is partly based on the Femto OS user's guide
[3] ATM18 AVR Board, Elektor, April 2008
[4] ATM18 Relay Board and Port Expander, Elektor, October 2008
[5] www.elektor.com/090843
[6] www.atmel.com/avrstudio
[7] winavr.sourceforge.net

External interrupts

Femto OS can handle external interrupts in two ways: by setting an event flag or by using an interrupt service routine (ISR). The event flag can be used to wake up a high priority task which is waiting for this event. This task will then run at the next tick interrupt.

There are two ISR flavours: ISR I and ISR II. An ISR of type I can be reached after an interrupt from (almost) anywhere in the program, whether it is in task space or OS space, but it has limited functionality. An ISR of type II can only be reached from within a task. If such interrupts happen while the OS is running, their execution will be postponed until a task is started. Such interrupts can also force the currently running task to yield just before or right after the execution of the ISR.

The loudest!

By Ton Giesberts (Elektor Labs) &
Thijs Beckers (Elektor Netherlands Editorial)

Elektor Live! 2009 was almost there. In the weeks leading up to the event, Ton Giesberts was busy in the Elektor lab with designing, measuring, testing and building of a sufficient number of 'Portable PAs' (as they are called in-house) to support the speakers at the event. Ten units had to be assembled by hand. When soldering the parts of the (mostly SMD populated) boards, our own SMD oven and a few extra hands from interns came in very handy!

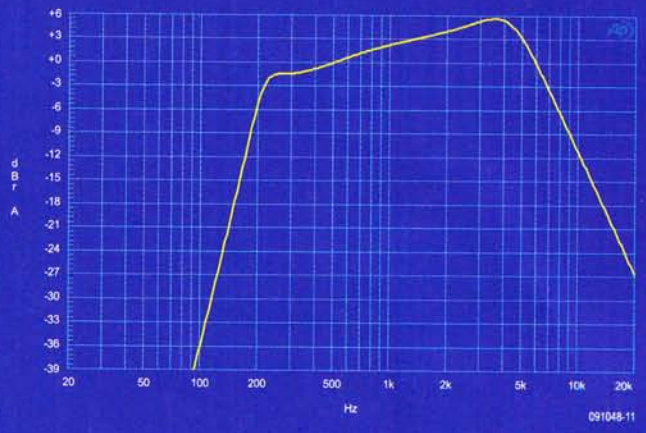
To help the speakers to be more intelligible in front of their audience, it was our intention to make the box amplify the higher frequencies a little more to improve the intelligibility and make the speech sound clearer. This objective was achieved. The upper curve shows the frequency response of the circuit without the frequency shifter, so only the microphone preamplifier in combination with the output stage. The frequency response increases with a slope of about 7.5 dB across the entire bandwidth from about 200 Hz to about 5 kHz. In the middle curve the frequency shifter is inserted in the signal path and we can see the frequency response of the boxes (produced in great haste) as they were used at the Live! event.

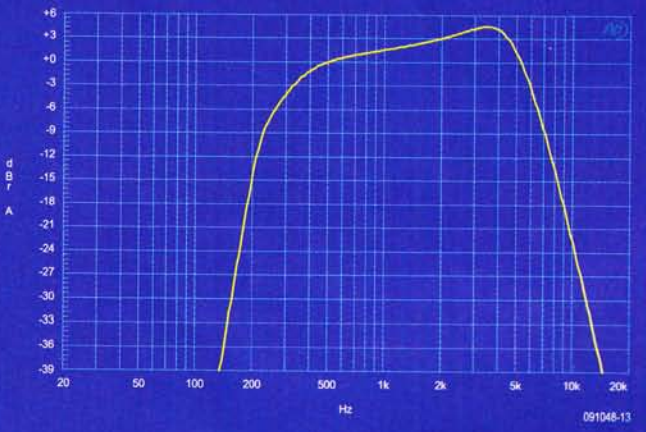
Also because of the extensive 'practical test' at the Live event we went back into the lab and did some further tests with the frequency shifter in the circuit and with the frequency shifter bypassed using a jumper between K1 and K2 (refer to the schematic of the article on the portable PA elsewhere in this issue). Doing these comparisons we had the impression that the acoustical feedback with and without frequency shifter occurred at much the same volume, although the sound was different. This was quite a strange result of course, since the theory behind the anti-feedback circuit is quite solid. Since the feedback frequency was quite high, we changed the filter components in the microphone and output amplifiers so that we now have a flat frequency response instead of a response that increases slightly with frequency. The frequency response now looks like the curve in the bottom figure. We chose Butterworth characteristics for the filters.

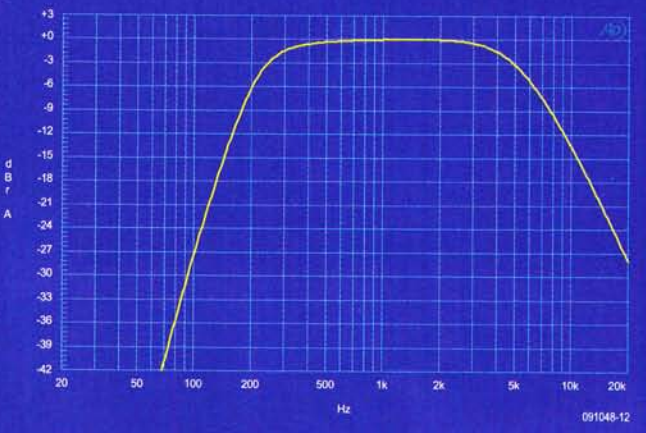
When comparing the modified box with an 'original' one the result appears to be positive. That means, the modified box could be turned up much louder than the original box before acoustical feedback occurred. So the design was a success.

In addition to these filter changes we also experimented some more with the frequency shifter. A shift downwards (the signal was shifted down in frequency compared to the original) resulted in a somewhat poorer performance than a shift upwards. The latter also makes the sound a little clearer, simply because all frequencies are reproduced a little higher.

As a result of these experiments, the characteristics of the filters in the modified box are the same as those in the implementation described in the article that can be found in this issue. We had the impression that the loudspeaker volume in this implementation could be turned up a little higher before acoustical feedback occurred. As a consequence of the adapted frequency response the sound has certainly become a little fuller, but the clarity of the voice is reduced a little, but this is very subjective of course, but worth the effort in our opinion.







If you would like to experiment for yourself with the characteristics of the filters on the microphone/output amplifier PCB then here are the component values for the increasing frequency response characteristic that we used originally.

R5 = 2k2	R6 = 6k8
R7 = 12 k	C2 = 100 n
C5,C6,C7 = 100 n	C12 = 22 n
C13 = 1 n	

(091048)

E-LABS INSIDE

PCB design – it's not witchcraft!

For many electronics enthusiasts it's no big deal selecting the right transistor for a circuit, calculating an appropriate capacitor value or choosing the right logic ICs to perform a particular function when needs must. After this it's little more effort to knock up the circuit on a breadboard or soldering it up on a scrap of Veroboard. Job done!

On the other hand, designing a matching printed circuit board (PCB) is a tougher challenge for many electronics enthusiasts. In some cases a substantial number of components need to be laid out in a logical and functional manner, all the time checking minimum inter-track clearances, smallest sizes for solder pads and all matter of other issues.

Have no fear though — designing a PCB is certainly not witchcraft. At Elektor Labs we develop several dozen boards a year, both using surface mount devices (SMDs) and also for through-hole (TH) placement. It's true that lab director Antoine Authier's team have a customised version of Altium Designer (a powerful CAD program) at their disposal, which provides elaborate simulation and auto-routing capabilities. Actually, however, these functions are used relatively infrequently, reports Chris Vossen, in charge of many microcontroller and Test & Measurement projects in the lab.

"When we line up components I try to transfer each of the circuit's functional groups onto the PCB as a complete entity," says Chris. The power supply, the microcontroller plus its support circuitry and the analogue electronics are types of blocks that are seldom subdivided down to their individual components. Altium enables multiple components of the schematic to be tagged simultaneously (see illustration), so that they can then be placed on the PCB and moved around as a group. That said, Chris can manipulate individual components by hand almost as rapidly.

Another feature of the CAD package is more significant: maintaining a set minimum distance between the tracks (traces), between solder pads and finally between pads and tracks. In its board-view mode Altium Designer uses colour codes to indicate whether all these requirements have been observed correctly, even when routing is carried out manually. In Altium this is an interactive process, whereas many other CAD programs carry out the design-check with the press of a single key.

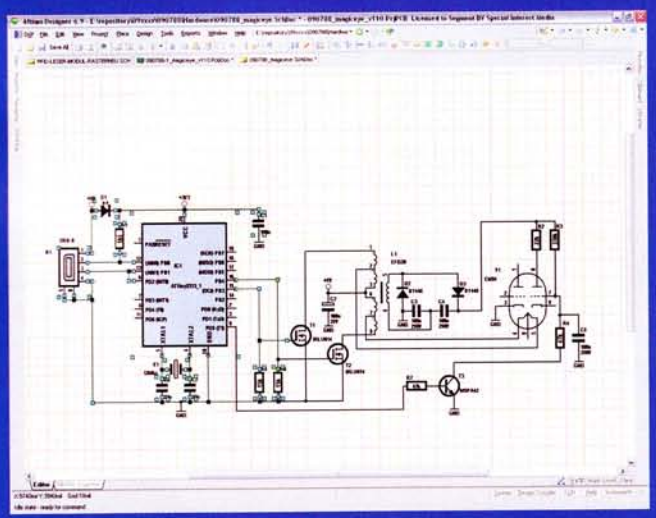
With SMD boards, which are sold (partially) populated in the Elektor Shop, the Elektor developer must maintain a minimum separation of 0.15 mm. This is laid down by our PCB producer, Eurocircuits, to meet the European 'Class 6' regulations [1] that Elektor aims to observe. "On boards that users themselves will fit out with components I increase the separation to 0.3 mm, to make their task simpler," adds Chris. To make the soldering task even more user-friendly the Elektor Labs staff also increase the solder pad dimensions for many commonly used components by 2 mm or more.

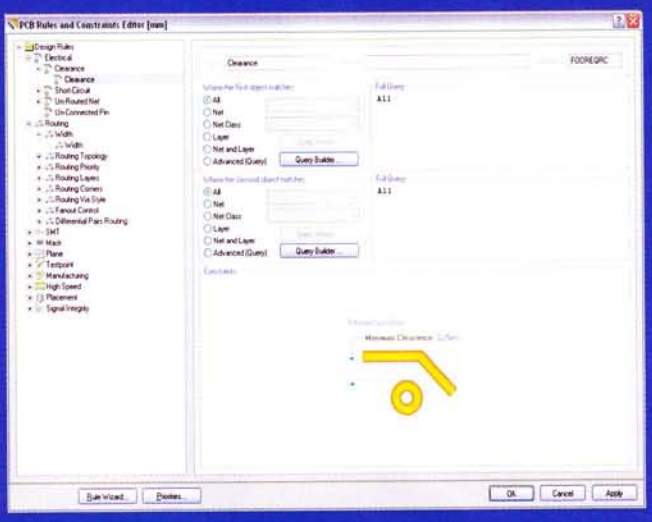
"On boards that don't have to be ultra-compact I also make the tracks a bit wider than usual," continues Chris. For our USB-to-Magic Eye adapter [2] (see photos) the tracks are almost entirely 0.7 mm wide. One exception is the tracks running between two pins of the microcontroller, which were drawn manually a bit narrower for clearance. Where high currents are involved Chris prefers to use free calculation programs on the Internet, such as the one at [3]. You can set parameters such as the thickness of the copper track layer (generally 35 µm for Eurocircuits), the current, peak voltage and so on.

It's natural that people who carry out PCB design as part of their daily work build up plenty of experience. Our Elektor designers and editors have compiled the following digest of tips for laying out components, routing and more.

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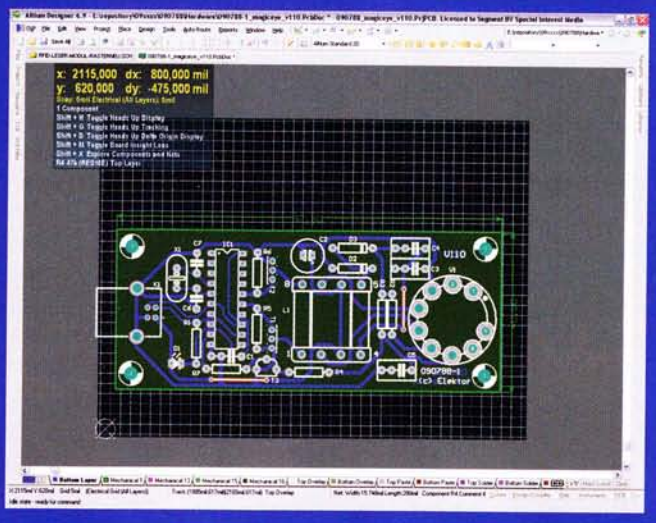
[1] www.eurocircuits.com/images/stories/classification%20january%202009.pdf
[2] www.elektor.com/090788
[3] http://desmith.net/NMdS/Electronics/TraceWidth.html
[4] http://www.elektor.com/magazine/construction-electrical-safety.83362.lynkx

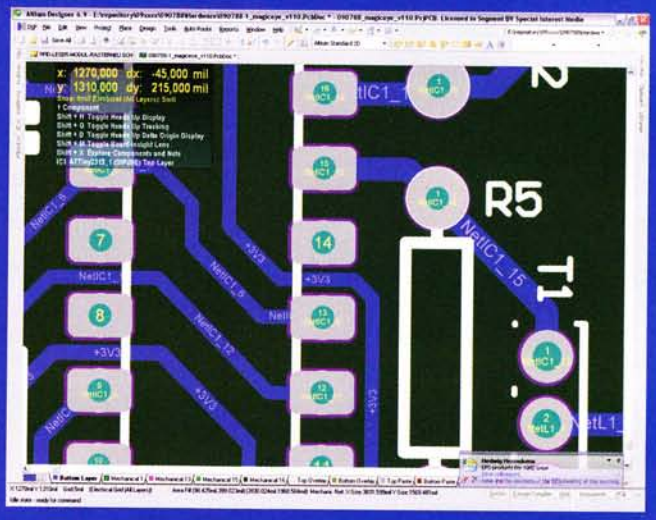




PCB design tips

- When compactness is not a major consideration and the boards will be assembled by hand, through-hole components are the better choice. In this case you can use the pins of these components as 'vias'.
- On the other hand surface-mount components can save a whole load of drilling on self-made PCBs. They make it simpler to achieve objectives such as minimum length for tracks (British English) or traces (American English), minimal area inside track loops, etc.
- The orientation of components should consider not only simplicity of assembly but also the need to test the circuitry afterwards. This is the time to remember the need for test points!
- The place for switches, press buttons, plug-in connectors, LEDs and other user-interface components is outside the enclosure. Anything requiring subsequent access should be on the front panel of the case.
- Components that require assembling with the right polarity should all have the same orientation.
- Manual routing is preferable to using the autorouter. The latter has its uses nevertheless for discovering bottlenecks and other critical points.
- When routing never even think about giving up! Many PCBs appear 'unroutable' at the outset, yet after a while it turns out you have plenty of space to spare.
- If you're not satisfied with your efforts, it's better to go back a step or two rather than just muddle onwards.
- Complete the routing for each of the functional groups of the circuit first. Link the groups together only after you have finished this stage.
- Short tracks are better than long ones. High impedance connections are more sensitive to interference and for this reason require to be kept as short as possible.
- Where tracks form a loop, their surface area should be kept to an absolute minimum.
- Decoupling capacitors must be located as close as possible to the switching element that needs to be decoupled.
- Tracks carrying signals should be routed early on (first the short ones, then the long ones). Except, that is, when the power supply tracks are particularly critical.
- Bus lines should be routed alongside one another.
- Separate analogue circuitry from digital whenever possible.
- On multilayer boards arrange tracks carrying signals so that one of the layers hosts the vertical tracks and another one accommodates the horizontal ones.
- If possible reserve one layer or side exclusively for a continuous ground plane. Only in exceptional situations, e.g. with high speed op-amps, is this undesirable.
- Keep tracks carrying heavy currents well away from sensitive pickups, sensors and suchlike.
- Beginners should take special care with mains and high voltages! The normal rule for (European) Protection Class I [4] requires a minimum separation of 3 mm between a track carrying mains voltage and any other track or the casing. At Protection Class II this distance rises to a minimum of 6 mm (between a track carrying mains voltage and the case, between multiple mains tracks or between mains tracks and low-voltage sections of the circuit). For the other regulations see [4].
- Ground and earth tracks require exactly the same consideration as the power supply tracks. Electromagnetic interference can be minimised by keeping the power and ground tracks parallel (or better still arranged over each other on either side of a double-sided board).
- Bends should be no more than 45°. Sharp angles between the tracks and the pads are also to be avoided.
- Observe PCB manufacturers' requirements without exception in order to avoid unpleasant surprises later.
- If you are using software for checking conformity to specifications, carry out these checks regularly at each design phase.
- A border of 0.12" (approx. 3 mm) around the edge of the PCB should be kept entirely clear of components.
- If components are to be inserted by machine you must provide at least three location marks.
- Don't forget the holes for fixing screws or pillars!
- Don't skimp on text markings on the PCB: indicate polarity, voltages, on-board functions, part designation, design date, version number...
- Check not just twice but three times that all components will actually fit the PCB!
- Leave time at the end of the process for some tidying up and

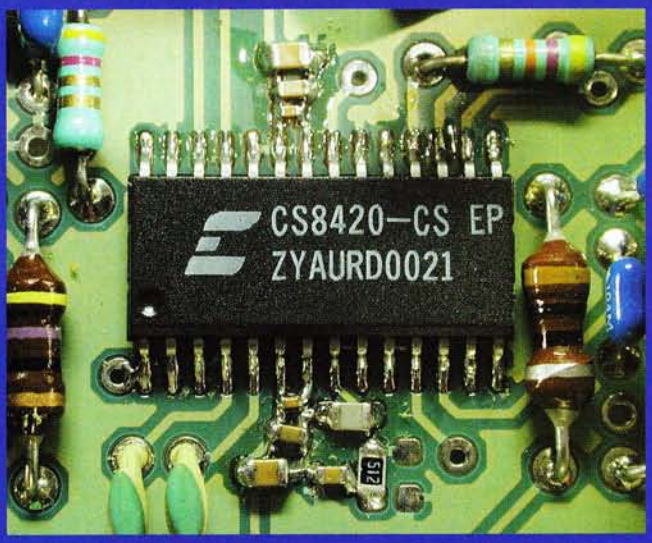




Capacitors to the rescue

Jens Nickel (Elektor Germany Editorial)

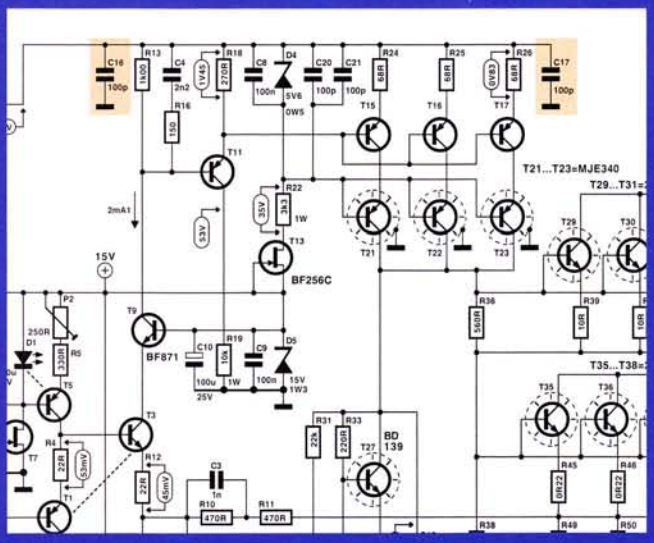
The team here in the Elektor lab are a good mix of young engineers and some more experienced 'veterans'. Ton Giesberts has been with Elektor now for over 20 years so I guess he would count himself as one of our 'vets'. Audio design is Ton's area of expertise. He has been responsible for many excellent projects and given valuable input to almost every article that concerned itself with high quality audio appearing in this publication over the last 20 years. With his experience it's no surprise that he sometimes gets a Déjà-vu moment when a new design lands on his desk. The portable 'PA amp' featured in this month's magazine [1] is a case in point. It uses the MAX9768 class D amplifier from MAXIM which according to the application note requires four capacitors for supply decoupling. Both a 33 µF and a 1 µF capacitor are connected in parallel to the two voltage supply pins to ensure suppression of the widest range of frequencies. 'The chances are that internally this chip has two output stages' Ton suggested was the reason for the two supply pins. It reminded him of the 96 kHz sampling rate converter which he authored in the April 2001 edition of Elektor [2]. This used three capacitors in parallel for supply rail decoupling; one 1 µF, one 100 nF and one 1 nF. If you look closely at photos of the prototype in the article you can see three different sized SMD capacitors mounted next to each other at either side of the CS8420 chip. 'When a manufacturer indicates this kind of detail in a data sheet or application note it is wise to follow their recommendation' advised Ton. 'And another thing, when a low ESR or high ripple current type of electrolytic is specified in the parts list there's usually a good reason for it!'



It's not only important to check the voltage rating of an electrolytic but also its ripple current rating. Ton had first hand experience of this as a young engineer. One of his earlier designs was a 650 W DC inverter for an in-car audio amp or 'car booster' which featured in the October/November editions in 1994. 'For capacitors C18 and C19 I just used standard 10,000 µF radial electrolytics' he explained 'however during the first soak test on this design I found a major problem, after power up the thing began running so hot I could actually feel the heat from some distance away'.

A loud crack ensued and superheated capacitor internals flew around the lab. After a rethink 8,800 µF 'Sikurel' type electrolytics from Siemens, were substituted in the design and were specified in the parts list.

Capacitors came to the rescue of another large project that Ton had been working on for over a year but this time they were a much smaller variety. The beast in question was the Titan 2000 power amplifier. This fully symmetric high power mono audio amplifier is capable of delivering up to 2000 W in a bridge configuration. It was one of the most complex designs ever featured in Elektor [3] with no less than 52 transistors some of which were sourced from the supplier at that time (Avera) in Japan. With all the theoretical work behind him and the first 25 x 10 cm prototype board fully stuffed with components, switch-on came as something of a shock; 'With no input signal the output would just hang, sometimes at +70 V sometimes at –70 V' It didn't take him long to find that the amplifier was oscillating but at such a high frequency the voltage amplifier couldn't keep up.



To track down the source of instability Ton armed himself with a handful of 100 pF capacitors and a scope. First for some HF decoupling of the supply rails, with just one capacitor on each rail there was little improvement but after placing four at points along the length of each rail (in such cases 'cut and try' is often the only way to go to find the most effective positions) peace broke out, the oscillations ceased and the amp became stable.

(090876)

[1] www.elektor.come/090675
[2] www.elektor.com/010014
[3] www.elektor.com/990001

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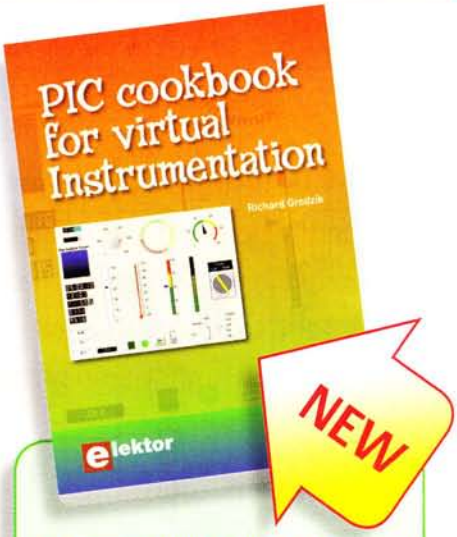
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Loud and Clear

A portable sound system with feedback suppression

By Ton Giesberts (Elektor Labs) and Thijs Beckers (Elektor Netherlands Editorial)



Sometimes it's helpful to raise your voice just a bit. Regardless of whether the occasion is a guided tour or a presentation in a noisy room, that little bit of extra volume may be enough to ensure that everyone can understand you. However, you have to watch out for feedback with this sort of personal PA system.

For the Elektor Live! 2009 event [1], we wanted to make things a bit easier for the speakers in the rings of the Philips Evoluon building [2] by designing a portable public address system that is small and light enough to be carried on the user's belt. The problem with such a design is that due to the relatively small distance between the loudspeaker and the microphone, there's a fairly good chance of feedback howl. This occurs when the headset microphone picks up the sound from the loudspeaker, amplifies it, and emits it again via the loudspeaker, which produces an irritating howling tone. For this reason, we incorporated a previously published anti-feedback mechanism in our design: a frequency shifter.

Frequency shifting

The most important consideration in this application is avoiding feedback. The loudspeaker is carried at waist height and is thus relatively close to the microphone. With a static configuration, an adjustable narrow-band blocking filter (a notch filter) is a good option. However, in our application the microphone and the loudspeaker move relative to each other when the speaker's head moves. This means that the filter tuning would need to be adjusted continuously. Nowadays it's possible to implement this sort of thing with a digital signal processor (DSP), but we considered this option a bit over the top for a DIY project.

Manual adjustment of the notch filter is impractical, so we had to take a different approach to suppressing feedback. We published an article on a 'feedback killer' in the February 1990 issue of Elektor Electronics (as the magazine was called then). This circuit appeared to be a good choice for our purpose. It raises or lowers the frequency of the input signal by a few hertz so the output signal differs slightly from the input signal. This prevents the repeated amplification of

Features

- Maximum output power 10W/8 Ω (with 14 V supply)
- Feedback suppression by frequency shifting
- Suitable for electret and dynamic microphones
- Low current consumption
- Can also be used without the frequency shifter as a portable active speaker

a particular frequency (the feedback frequency). Of course, we modified the original circuit somewhat for our application.

This feedback killer works as follows: all-pass filters are used to split the input signal into a pair of signals with a 90° phase difference. These two signals are mixed with two clock signals (carrier wave), which also have a phase difference of 90 degrees. The resulting signals are then summed. This produces a signal corresponding to the sum of the input signal and the carrier signal.

There are a few difficulties with this approach. For proper operation, the signals must have a phase difference of exactly 90°, but the all-pass filters cannot achieve this fully. In addition, a sinusoidal signal should actually be used as the carrier signal instead of a square-wave signal. However, the circuitry necessary for signal mixing is much simpler with a square-wave signal. As a square-wave signal can be regarded as the sum of sinusoidal signals, this can be corrected reasonably well by using a low-pass filter to eliminate everything except the desired mixer product.

In order to obtain the desired frequency shift of the input signal, the sum signal is mixed with a signal at almost the same frequency as the carrier signal. This produces all sorts of sidebands in the frequency spectrum, but we want to keep only one of them. Accordingly, we filter the other ones out. The frequency difference between the two carrier signals determines the ultimate frequency shift of the input signal. For a mathematically formulated version of this arrangement, see the original article published in 1990.

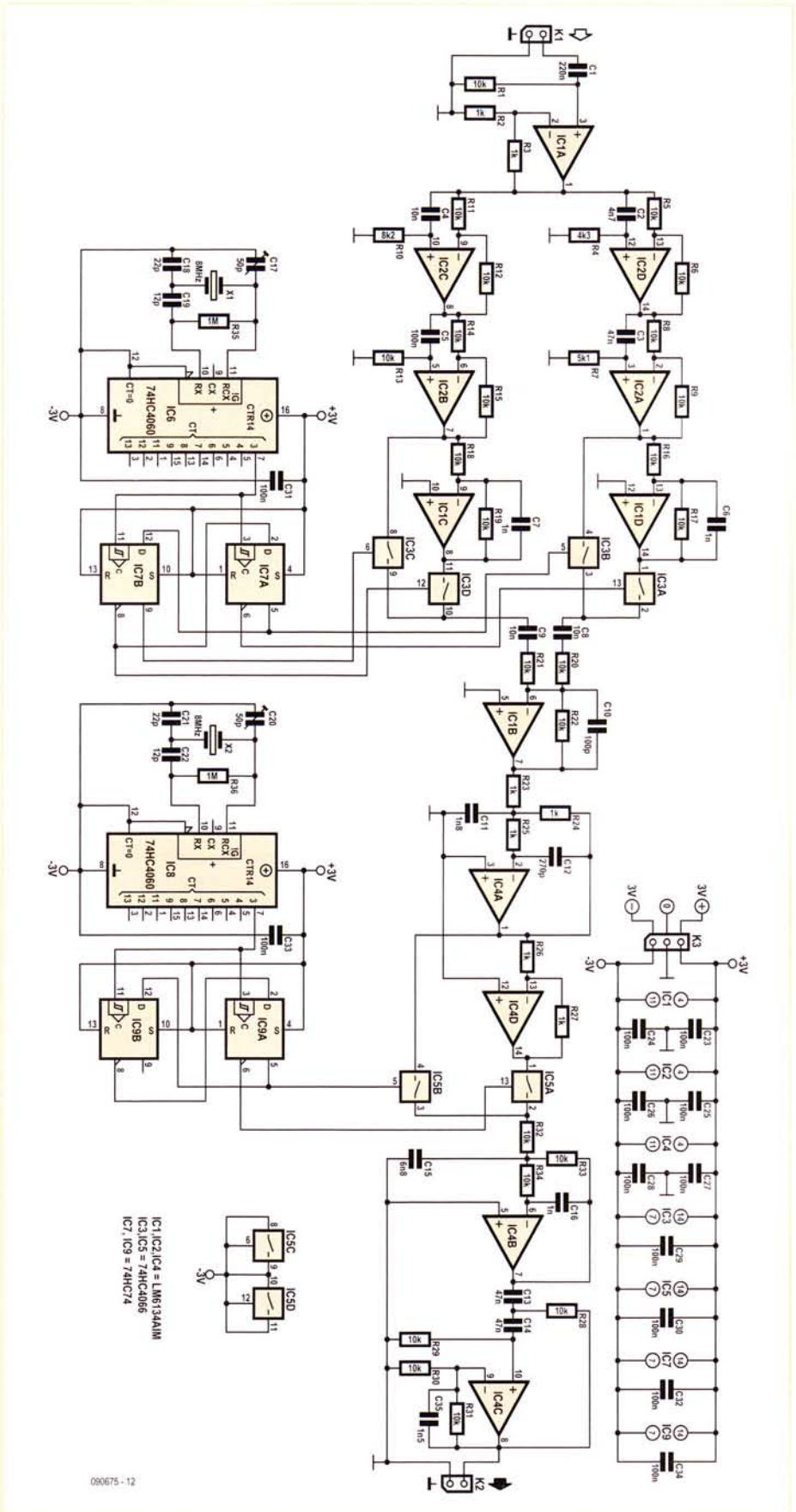


Figure 1. As you can see from the schematic diagram, the frequency shifter employs quite a few opamps.

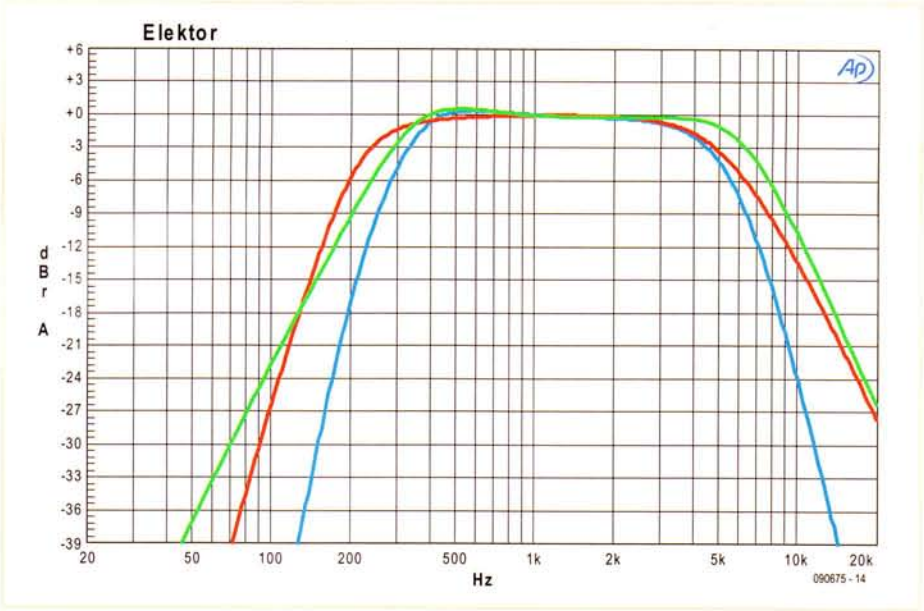


Figure 2. The frequency response curves of the frequency shifter (green), the microphone amplifier with output amplifier and filter (red) and the overall circuit (blue).

Upgraded implementation

The present circuit is battery powered, so we took several measures to reduce the current consumption, including using half as many all-pass filters. This eliminated one quad opamp. For the opamps, we selected rail-to-rail devices from National Semiconductor that combine low current consumption (360 µA) with high bandwidth. This alone yielded a savings of 18 mA.

In addition, the supply voltage from four alkaline cells (6 V) is considerably lower than the supply voltage of the original design (around 8 V), and we used the faster HC family of logic devices. The net result is that the current consumption of the entire circuit (under quiescent conditions) is now only 15 mA instead of 45 mA as in the original design. The choice of HC logic devices prevents the use of a higher supply voltage, although the opamps can handle a higher voltage (24 V).

We also changed the component values in a few places. The input amplification is reduced by a factor of 2 because the supply voltage is a good deal lower (see **Figure 1**). The low-pass filters are built around IC2a–IC2d. The pass band of the phase shifter is approximately 300 Hz to 4 kHz (±2° deviation), which is good enough for speech.

We selected Texas Instruments devices for the analogue switches on account of their very low resistance. This allows the resistances of the summing opamp (IC1b) to be reduced by a factor of 10, which yields less noise and better signal processing. Capacitor C10 limits the bandwidth of the mixer input signal in order to reduce the harmonics in the mixer output signal. The opamp is followed by a low-pass filter that further suppresses undesired harmonics.

In order to keep the noise level low, the resistance values of the subsequent inverter are also an order of magnitude smaller than in the original 1990 circuit. The mixer is followed by a low-pass filter and then a high-pass filter. This arrangement prevents the high-pass filter from letting through undesirable harmonics from the second mixer.

The corner frequency of the low-pass filter is slightly more than 7 kHz. The corner frequency of the high-pass filter is approximately 270 Hz (see **Figure 2**). Capacitor C35 reduces the gain to 1 at high frequencies. As a result, the frequency response curve drops by 1.7 dB from 460 Hz to 4 kHz. The filter has been redesigned to have a characteristic resembling a 1-dB Chebyshev filter, which makes its cut-off a bit sharper. As a result, the gain is somewhat higher at low frequencies, but this is more than offset by the characteristics of the filters of the microphone and output amplifiers. The coupling capacitor at the input (C1) has virtually no effect on the amplitude curve (it flattens the curve by 0.1 dB).

The maximum frequency shift can be set using C17 and/or C20 and is approximately 30 Hz. The amplitude modulation (a ripple signal at the shift frequency) is 7.5%. This is due in part to the simplification of the all-pass filters and in particular the component tolerances, which have a detrimental effect on the operation of the circuit. The end-to-end gain is approximately 2.7 with small signals. It is somewhat less with larger signals (2.55 at 100 mV).

The lowest distortion level (0.23% as measured with our prototype) occurs at an input signal level of 10 mV. The distortion increases with increasing input signal level to 1% at 30 mV and 3.2% at 100 mV, as measured with a frequency shift of +13 Hz.

Microphone amplifier and output amplifier

For obvious reasons, the enclosure that holds the circuitry, loudspeaker and batteries should not be overly large. Consequently, both PCBs are designed to use SMD components. This leaves a reasonable amount of space for the loudspeaker, which uses the enclosure as a speaker box. The amplifier board comprises a microphone amplifier, a high-pass filter and a class D amplifier with a low-pass filter (see **Figure 3**). The latter filter is combined with the driver stage of the output amplifier.

In order to provide the usual supply voltage to an electret microphone, we used a standard phantom supply circuit with a 2.2-kΩ resistor connected to the supply rail (for a total resistance of 2.42 kΩ including the decoupling resistor). The resulting open-circuit voltage is 3 V. If you use a dynamic microphone, you can omit R2 (2.2 kΩ).

Balanced supply voltages for the microphone amplifier are obtained by tapping off the ground level from the middle of the battery chain. The microphone supply voltage is adequately decoupled by R1 and C1. The DC offset voltage of the microphone is decoupled by C2.

We chose an ST dual rail-to-rail opamp for the subsequent amplifier stage: the TS922ID, which we have used previously in other projects. The amplifier stage is designed to have adjustable gain in order to compensate for large differences in the sensitivity of various types of microphones. The gain can be adjusted over a range of 1 to 21 with P1. This arrangement also allows the

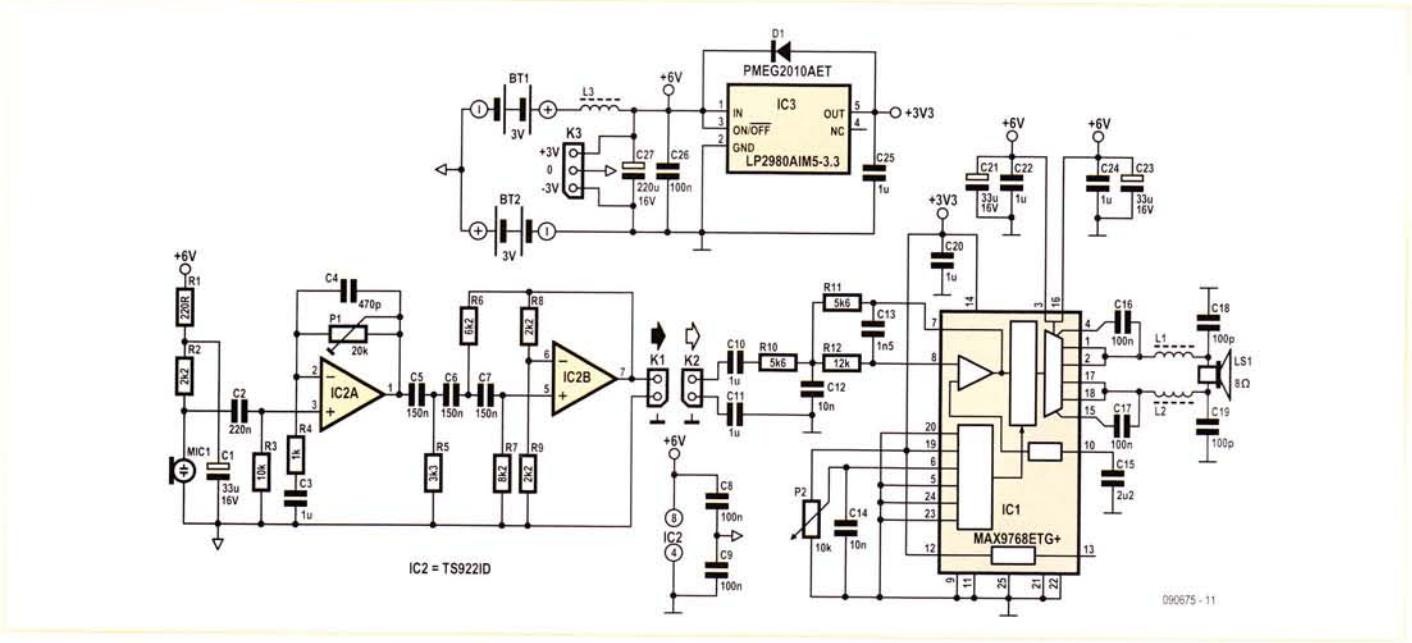


Figure 3. The microphone and output amplifier board is laid out so that it can be used without the feedback shifter board. Only one jumper between K1 and K2 is necessary for this.

circuit to be used as an active loudspeaker for an MP3 player or similar device (with R2 omitted as necessary). At maximum gain, the bandwidth is reduced somewhat by C3 and C4.

In light of the fact that the enclosure is worn on the user's body and makes use of a headset with a microphone, a third-order high-pass filter with a gain of 2 is placed after the input stage. This provides adequate suppression of low-frequency rumble and eliminates the problem of reproducing low frequencies with a small loudspeaker. The filter is a Butterworth type with a corner frequency of approximately 240 Hz.

The output of the preamplifier stage is feed to connector K1 for connection to the frequency shifter. The input of the output amplifier (K2) is located right next to K1. This way the output amplifier can be connected directly to the microphone amplifier by a simple jumper.

The ground level of the input stage is half the supply voltage, while the ground level of the output amplifier is the negative battery voltage. A capacitor (C11) is connected in series with the ground terminal of the output amplifier input to decouple this voltage difference.

With the voltage available from four penlight cells, an output power of 2 W into 8 Ω is possible with a bridge amplifier. For the output amplifier, we looked for an IC that can also handle more than 5 V. We chose a very nice (extremely small) IC from Maxim, the MAX9768ETG+, which comes in a 4 × 4 mm 24-lead TQFN-EP package. The power stage has an operating supply voltage range of 4.5 V to 14 V. Despite its small dimensions, this IC can deliver 10 W to an 8-Ω loudspeaker with a 14-V supply voltage. At 6 V the figure is 2 W into 8 Ω, or nearly twice as much into 4 Ω. The power dissipated in the IC is transferred to a copper plane on the PCB by an exposed pad on the bottom of the package.

Power supply

The amplifier IC has a separate driver stage that operates at a lower supply voltage (2.7 V to 3.6 V). The driver stage can be configured to provide extra gain. It needs a separate 3.3-V voltage regulator. To allow this board to be connected to a higher supply voltage if so desired, the voltage regulator must be also be able to handle the higher voltage. One of the few devices that meets this requirement is the National Semiconductor LP2980AIM5-3.3. This IC, which comes in an SOT23-5 package, can handle up to 16 V. Note however that the maximum rated voltage of the TS922 is 12 V, which makes this the maximum operating voltage of the microphone and output amplifier board without further adaptations. Schottky diode D1 protects the voltage regulator if the input voltage is less than the output voltage, which may for example occur if the batteries are shorted.

The voltage regulator has an extremely low dropout voltage of only 60 mV at 10 mA. This means that the entire circuit will still operate even when the batteries are close to empty. If the voltage drops below 4 V, the undervoltage lockout will disable the IC. With regard to the features of the IC, such as the patented spread-spectrum modulation, see the data sheet. There are far too many features to describe here, even in summary form.

Here we took advantage of the possibility of using a potentiometer (P2) to control the volume. We selected spread-spectrum modulation with filterless mode. We were guided primarily by the typical application circuit in the data sheet, and we used the evaluation kit as reference for the layout. The passive output filter that is usually necessary can be omitted in this application because the speaker leads are shorter than 20 cm. However, we did fit ferrite chokes (L1 and L2) in the speaker output lines. Capacitors C18 and C19 enhance the HF filtering. The selected SMD chokes (0805 package) have a DC resistance of only 50 mΩ and can handle 2 A. This corresponds to the maximum current of the MAX9768 (soft output current limit).

The supply voltage for the power stage of the IC is fed via two pins. Each pin is well decoupled with its own electrolytic capacitor (C1 & C2). Here we used a somewhat pricey type from Nichicon with a low ESR

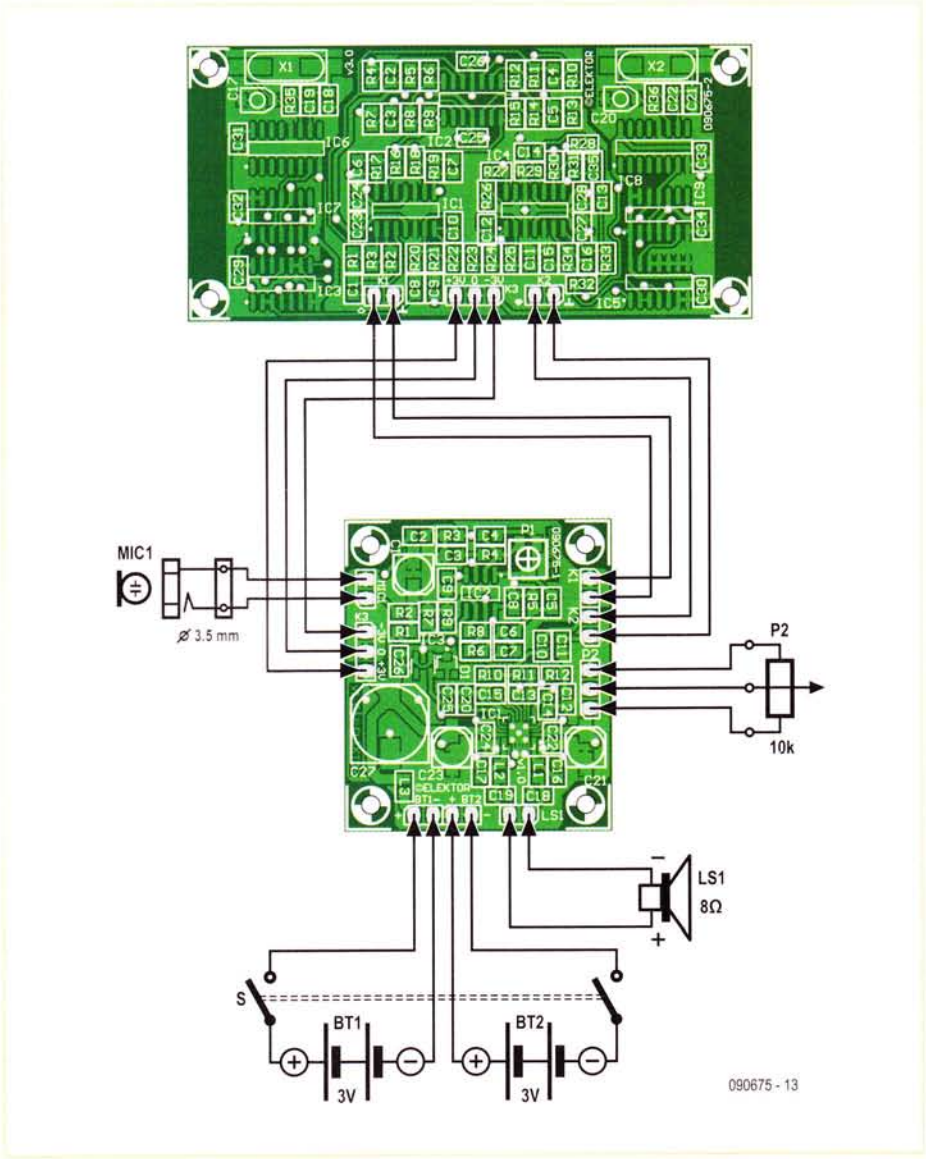


Figure 4. Follow this wiring diagram to connect everything together.

that can handle 1.9 A. The supply voltage connection on the PCB is additionally decoupled by a relatively large electrolytic capacitor with a low ESR that can handle a hefty 3.4 A. It is important to use high-quality electrolytic capacitors in order to obtain a reasonably long service life from the circuit. The circuit operates with a fairly high switching frequency (300 kHz ± 7.5 kHz), and normal electrolytic capacitors are not suitable for this. The battery connection is additionally decoupled by a small choke (L3).

The volume control input is decoupled by C14. A connector is used for the potentiometer leads so the potentiometer can be fitted independent of the position of the board. The volume can be adjusted in 64 steps. The volume range is approximately 100 dB, which is easily more than enough. The internal gain of the IC is 9.5 dB maximum from the volume control stage (see also Table 6 in the data sheet) plus 20 dB from the output stage. The maximum total gain is thus around 30 dB.

Additional gain can be configured with the driver stage. This is done using two resistors, just like a standard inverting amplifier built around an opamp. We took advantage of this option to incorporate a second-order low-pass filter without having to use another IC. The inverting input can be used to construct a second-order multi-feedback filter. This is implemented as a second-order Butterworth filter to provide a gain characteristic that is as flat as possible over the desired bandwidth. The corner frequency is 5 kHz. The gain of this filter is -1. Feedback via the supply voltage may occur at higher gain.

Final assembly

The enclosure we used for our prototype has dimensions of 32 × 100 × 162 mm. With the loudspeaker, the battery holders and the two PCBs installed in the enclosure, there's not much space left over. We fitted a 3.5-mm stereo headphone socket, potentiometer P2, and a dual-pole switch on one side. The loudspeaker we used is too deep to mount on the inside of the enclosure as actually intended, so we mounted it on the outside of the enclosure.

The layouts of the two PCBs for this project can be downloaded free from the associated web page [3].

The PCB for the microphone and output amplifiers is fitted on the side, which is also where the connectors are located (switch, MIC1 and P2). If everything is laid out properly, the rear of the loudspeaker just clears the frequency shifter board. We made a flat hook bracket from a piece of aluminium (20 × 50 mm) for attaching the enclosure to a belt or trouser pocket. It is fitted to the back of the enclosure (level with the loudspeaker).

All connectors are implemented as pin headers, so you can use sockets for testing. After the boards are fitted in the enclosure, you can also solder thin stranded wire directly to the header pins. Twist the wires to be joined together (with two wires) or braid them together (with three wires) to reduce the likelihood of problems. Use somewhat thicker wire for the loudspeaker. The wiring diagram in **Figure 4** clearly shows how to connect everything together.

Of course, you can also use a different enclosure and select a different loudspeaker. Pay attention to the efficiency of the loudspeaker. According to the manufacturer's specifications, the efficiency of the type we used is 88 dB/W, but many loudspeakers with these dimensions have much lower efficiency. If a low-efficiency type is used, the output amplifier will not be able to supply enough power. In other words, you will need a higher supply voltage, which means more batteries. Note that the frequency

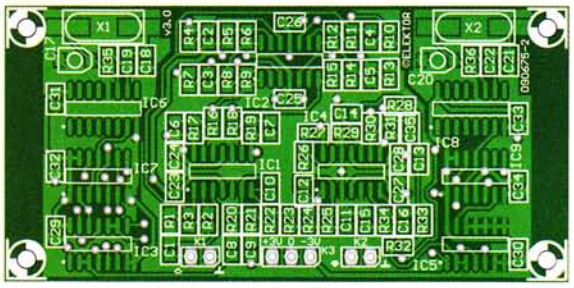
COMPONENT LIST Frequency Shifter

Resistors *(SMD 0805)*
R1,R5,R6,R8,R9,R11-R22,R28-R34 = 10kΩ 1% 0.125W
R2,R3,R23-R27 = 1kΩ 1% 0.125W
R10 = 8.2kΩ 1% 0.125W
R4 = 4.3kΩ 1% 0.250W
R7 = 5.1kΩ 1% 0.250W
R35,R36 = 1MΩ 1% 0.125W

Capacitors *(SMD 0805, except C17,C20)*
C1 = 220nF 10% 25V, X7R
C2 = 4.7nF 10% 50V, X7R
C3,C13,C14 = 47nF 10% 50V, X7R
C4,C8,C9 = 10nF 10% 50V, X7R
C5,C23-C34 = 100nF 10% 50V, X7R
C6,C7,C16 = 1nF 10% 50V, X7R
C11 = 1.8nF 10% 50V, NP0
C12 = 270pF 5% 50V, NP0
C15 = 6.8nF 10% 50V, X7R
C10 = 100pF 5% 50V, NP0
C17,C20 = 50pF 25V, SMD trimmer, AVX type CTZ3E-50C-W1-PF
C18,C21 = 22pF 5% 50V, NP0
C19,C22 = 12pF 5% 50V, NP0
C35 = 1.5nF 10% 50V, X7R

Semiconductors
IC1,IC2,IC4 = LM6134AIM SMD (SO-14)
IC3,IC5 = 74HC4066 SMD (SO-14)
IC6,IC8 = 74HC4060 SMD (SO-16)
IC7,IC9 = 74HC74 SMD (SO-14)

Miscellaneous
X1,X2 = 8MHz quartz crystal, SMD, AVX type CX49GFWB08000H0PESZZ
K1,K2 = 2-pin pinheader, right angled
K3 = 3-pin pinheader, right angled
PCB # 090675-2 see www.elektor.com/090675



shifter is connected directly to the battery voltage, and its maximum supply voltage is 6 V. If the supply voltage is higher than this, a few more voltage regulators will be necessary.

Practical results

From practical experience, it appears that the most important factor in avoiding feedback howl is to use a good headset with a directional microphone located as close as possible to the user's mouth. The best way to avoid feedback howl is to ensure that the microphone cannot pick up the sound from the loudspeakers.

For best results, the frequency shifter should be configured for a positive frequency shift. With a bit of experimenting, you can readily find the best shift value by ear. For those of you with access to an accurate frequency meter, measure the difference between the frequencies at the outputs of D-type flip-flops IC7 and IC9. We found 13 Hz to be a good compromise between a 'robot voice' effect and feedback suppression. The tendency to feedback howl is further damped by the slight decrease in gain at higher frequencies. Although a negative shift can also be used, feedback is more likely to occur in this situation. A repetitive sliding tone occurs if the volume is set to high, since the frequency shifter prevents the generation of a continuous tone.

If you use the circuit as an active speaker, for example with an MP3 player, the frequency shifter can be omitted. This will reduce the current consumption by nearly half.

(090675)

Internet Links

[1] www.elektor.nl/elektorlive2009 (in Dutch)
[2] www.dse.nl/~evoluon/historie-e.htm
[3] www.elektor.com/090675

COMPONENT LIST Microphone & Output Amplifier

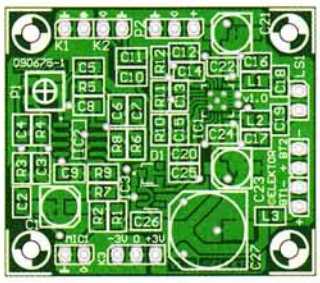
Resistors *(SMD 0805 except P1,P2)*
R1 = 220Ω 1% 0.125W
R2,R8,R9 = 2.2kΩ 1% 0.125W
R3 = 10kΩ 1% 0.125W
R4 = 1kΩ 1% 0.125W
R5 = 3.3kΩ 1% 0.125W
R6 = 6.2kΩ 1% 0.125W
R7 = 8.2kΩ 1% 0.125W
R10,R11 = 5.6kΩ 1% 0.125W
R12 = 12kΩ 1% 0.125W
P1 = 20kΩ 20% 0.250W, SMD, Vishay Sfernice type TS53YJ203MR10
P2 = 10kΩ 20% 0.250W, SMD, Bourns type 3310Y-001-103L

Capacitors *(SMD 0805, except C1,C21,C23,C27)*
C1,C21,C23 = 33µF 20% 16V, SMD chip type 5x6mm
C2 = 220nF 10% 50V, X7R
C3,C10,C11,C20,C22,C24,C25 = 1µF 10% 16V, X7R
C4 = 470pF 5% 50V, NP0
C5,C6,C7 = 150nF 10% 50V
C8,C9,C16,C17,C26 = 100nF 50V 10%, X7R
C12,C14 = 10nF 10% 50V, X7R
C13 = 1.5nF 10% 50V, X7R
C15 = 2.2µF 10% 50V, X7R
C18,C19 = 100pF 5% 50V, NP0
C27 = 220µF 16V 20%, SMD chip type 10x10mm

Inductors *(SMD 0805)*
L1,L2 = Murata type BLM21PG221SN1D (220Ω at 100MHz, 50mΩ, 2A)
L3 = Murata type BLM21PG600SN1D (60Ω at 100MHz, 25mΩ, 3A)

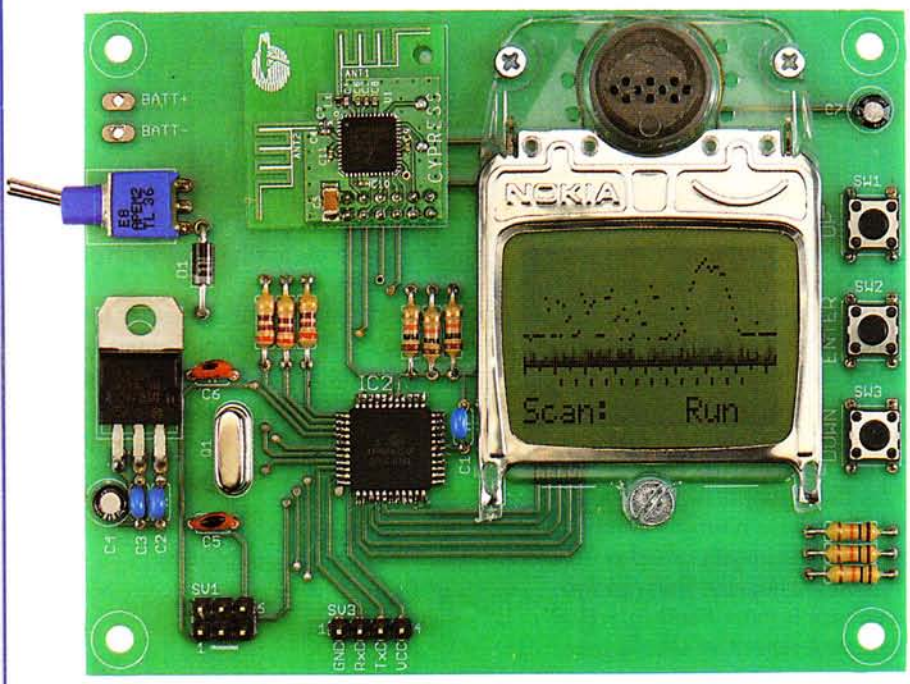
Semiconductors
D1 = PMEG2010AET (SOT-23) (1A 20V SMD Schottky diode)
IC1 = MAX9768ETG+ (TQFN-EP)
IC2 = TS922ID (SO-8)
IC3 = LP2980AIM5-3.3 (MA05B)

Miscellaneous
K1,K2,MIC1 = 2-pin pinheader, angled
K3,P2 = 3-pin pinheader, angled
LS1,BT1,BT2 = 2-pin pinheader, straight
2 battery holders for 2 AA cells
Loudspeaker, 2W 8Ω, e.g. Eurotec International type 59-F67.00-01FR
Enclosure, dim. 165 x 100 x 32 mm, e.g. MULTICOMP type MCRH3165 (Farnell # 1520395)
Switch, double pole double throw, 2A
3.5mm stereo jack socket for panel mounting
PCB # 090675-1, see www.elektor.com/090675



The 2.4 GHz Bandalyser

See what's happening on the band



By Marcel Romijn (The Netherlands)

The 2.4-GHz band is frequently used nowadays for wireless links between all sorts of devices. This often leads to problems with wireless local area network (WAN) links when different networks close by operate on the same channel. With this handy portable scanner, you can quickly and easily see which frequencies are being used in your area and which channels you should avoid for your own wireless network links.

The world around us is full of electromagnetic signals. Some parts of the electromagnetic spectrum can be used without a licence. One section of the RF spectrum that has become very popular in recent years is the 2.4-GHz band, which is one of the Industrial, Scientific and Medical (ISM) bands [1]. Many applications make use of this band. To mention just a few: WiFi LANs, BlueTooth, wireless computer peripherals, transmitters for remotely controlled model cars and planes, wireless music players and loudspeakers, and so on. Interference sources such as microwave ovens also operate in or near the ISM frequency allocation.

With the increasing use of this band, the likelihood of unwanted interactions between these applications, or even interference, also increases. If you have a problem with interference, how can you track down the cause? One solution is to use a scanner that shows you which signals are being transmitted in the 2.4-GHz band, such as the 2.4-GHz spectrum analyser published a few years ago in Elektor [2].

The 2.4-GHz scanner described here is based on that design, but it has a major advantage compared with the original design: it is implemented as a portable instrument with its own display, so you don't need a separate PC. A built-in microcontroller scans the 2.4-GHz band and shows the results on a graphic LCD screen. The scanner employs the same front-end module as the original design — a Cypress Semiconductors CYWUSB6935 — but the module is driven directly by the microcontroller via the SPI interface, which considerably boosts the scanning rate.

How it works

The scanner works exactly the same way as the previously published 2.4-GHz spectrum analyser.

Only the received signal strength indication (RSSI) portion of the CYWUSB6935 module is used here (see the block diagram in **Figure 1**). The microcontroller first tunes the frequency synthesizer to one the channels in the 2.4-GHz band and waits until the front-end module indicates the signal strength in the selected channel. Then it switches to the next channel and repeats the measurement process. As soon as all the channels in the band have been scanned this way, the measured data is used to plot a scan on the LCD screen. To avoid missing fast-changing signals, each channel can be scanned several times in succession.

Features

- Scans all 84 channels of the 2.4-GHz band approximately 20 times per second
- Displays the maximum value measured in each channel
- Each frequency channel can optionally be measured several times in succession
- The entire 2.4-GHz band can optionally be scanned several times in succession
- 3.3 V operating voltage, stabilised by a low-drop voltage regulator
- Serial port for future expansion
- Built-in transceiver module allows the unit to be used for other (wireless) applications

The circuit

The circuit (see **Figure 2**) is quite straightforward and consists of several main components: a microcontroller (IC2) that handles the control tasks, the CYWUSB6935 module (MOD1) for scanning the 2.4-GHz band, a Nokia 3310 LCD module for output (NOKIA3310), and three pushbuttons (S1 to S4) for input. As the CYWUSB6935 module and the LCD module both have an operating voltage of 3.3 V, we decided to operate the microcontroller at this voltage as well. A low-drop voltage regulator provides a clean 3.3 V supply voltage, even when the circuit is powered from four AA or AAA cells (dry cells or rechargeables).

As already mentioned, the CYWUSB6935 module and the LCD module are driven by the microcontroller via the SPI bus. Connector K1 is also connected to the SPI bus to allow the microcontroller to be programmed or reprogrammed.

The serial port of the microcontroller can be accessed via connector K2. This port could potentially be used to let the circuit communicate with the outside world, although it is not used in the present scanner design. Note that this port also operates with 3.3-V signals.

The supply voltage of the scanner is also available on connector K2. This could potentially be used to power a MAX3232. In the other direction, this connector could be used to provide the circuit with a stabilised 3.3-V supply voltage, but in this case the voltage regulator would need to be omitted.

Instead of using this circuit as a scanner, it would be possible to use two assembled circuit boards to implement a wireless link (optionally with bidirectional communication). In this case the microcontroller could be used to perform the more difficult tasks, such as driving the CYWUSB6935, while a simple protocol could be used on the serial port. One of the units could be built without the LCD module and fitted in a robot, while the other unit could be used to view the robot's parameters and send commands to the robot. There are lots of potential applications, and we're sure that Elektor readers can come up with even more ideas.

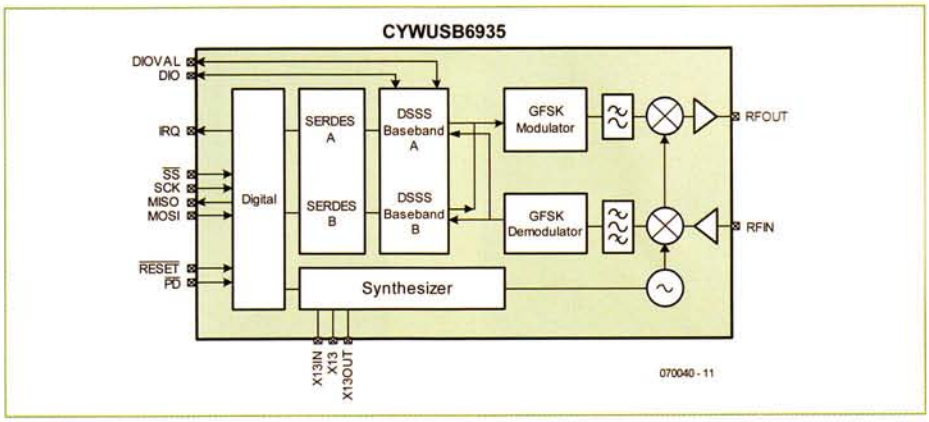


Figure 1. Block diagram of the Cypress CYWUSB6935 WiFi data transceiver.

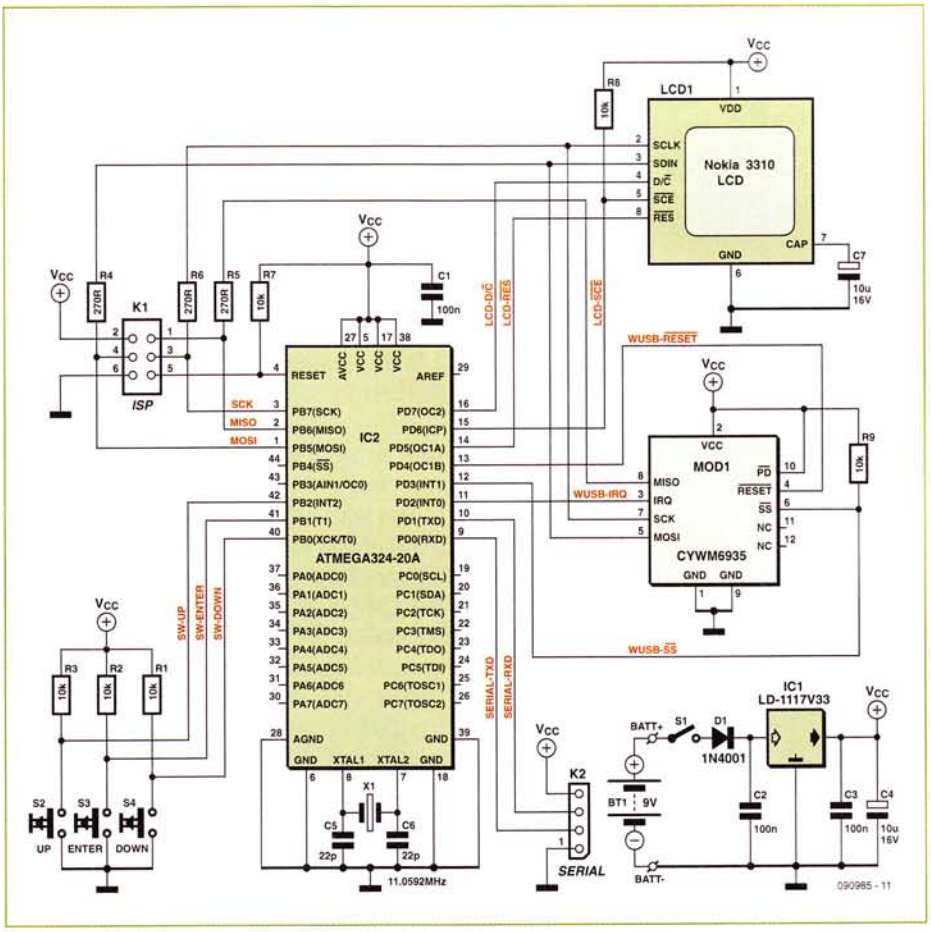


Figure 2. The main components of the circuit are an ATmega324, a Cypress WiFi module. and a display module from a Nokia 3310 mobile phone.

COMPONENT LIST

Resistors
R1,R2,R3,R7,R8,R9 = 10kΩ
R4,R5,R6 = 270Ω

Capacitors
C1,C2,C3 = 100nF
C4,C7 = 10µF 16V radial
C5,C6 = 22pF

Semiconductors
D1 = 1N4001
IC1 = LD-1117V33 (ST Microelectronics)
IC2 = ATmega324-20A (programmed, Elektor Shop # 090985-41)
MOD1 = CYWM6935 module (Farnell # 1319925/1321748; RS Components # 382-620)

Miscellaneous
X1 = 11.0592MHz quartz crystal
K1 = 6-pin (2x3) pinheader
K2 = 4-pin pinheader
S1 = miniature switch
S2,S3,S4 = pushbutton, 5mm, PCB mount
12-pin (2x6) connector for MOD1, lead pitch 2mm
LCD for Nokia 3310 mobile phone (search 'Nokia 3310 display' on Ebay)
9V battery with clip-on leads, or 4 AA or AAA cells with holder
Project software # 090985-11 and Eagle file for PCB # 090985-1, available free from [4]

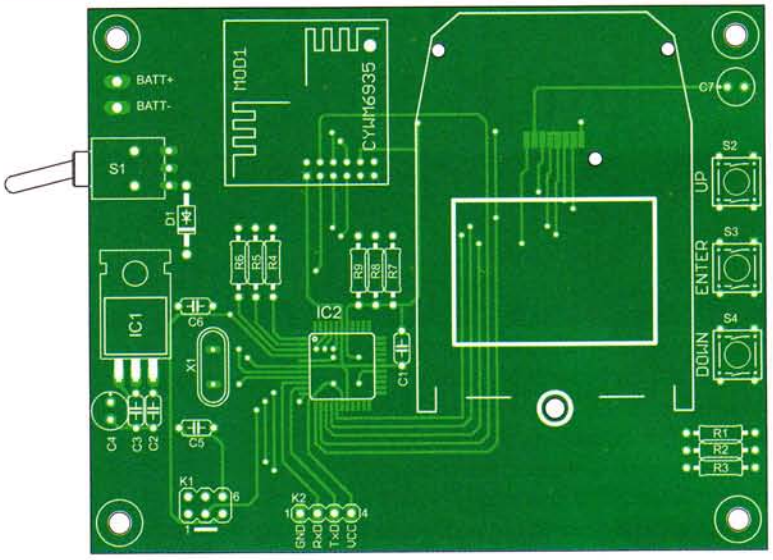


Figure 3. The spacious layout of the PCB makes assembly easy.



Figure 4. The display module consists of the actual display and a keypad section.

Construction

The author designed a PCB for the scanner (**Figure 3**) with a fairly spacious layout, so assembling the board should not present too many problems. Only one SMD component is used: the microcontroller, which comes in a 44-lead TQFP package.

The CYWUSB6935 module is ready to use and only has to be plugged into a header. Note however that the pin spacing is 2.00 mm instead of the usual 2.54 mm (0.1 inch).

You can buy the LCD module on the Internet at various sites, including eBay. The module comes with a flexible circuit that includes the contacts for the telephone keypad (see **Figure 4**). Remove the flexible circuit and saw the plastic substrate in two along the red lines shown in **Figure 5**. Be careful not to saw off the eyelet just below the display, since it is used for fitting the display.
To ensure that the display contacts are correctly aligned on the PCB, there is a plastic tab on the display that fits into a hole in the PCB. The LCD module can be fitted securely to the PCB with two M2 screws at the top and an M3 (3 mm) screw at the bottom, as can be seen in **Figure 6**.

Start the assembly process by fitting the microcontroller, since it is an SMD component. Soldering this IC requires a steady hand and a soldering iron with a fine tip. First secure the IC at one corner by soldering one lead in place, then align it precisely and solder the remaining leads. You can remove solder bridges between the leads afterwards with a bit of desoldering braid. After this, all of the other components can be fitted. Make sure that electrolytic capacitors C4 and C7 and diode D1 are fitted with the right polarity. The final assembly steps are to attach the LCD module to the board and plug in the CYWUSB6935 module. A 9-V battery provides an adequate source of operating power.

The firmware

The microcontroller can be programmed via connector K1. Note that the microcontroller has a supply voltage of 3.3 V, so it must be programmed using 3.3-V signals. The Atmel STK500 development module can be set to operate at 3.3 volts, so the microcontroller can be programmed using this module without any problems. If you only have a 5-V programmer, you will have to adapt the voltage level. You can use a MAX3392 for this as described in [3], or you can use a level shifter built from discrete components. The software is available on the Elektor website [4] as a free download. For readers who would rather not program the microcon-

troller themselves or are not able to do so, a pre-programmed IC is available from the Elektor Shop (item # 090985-41).

The user interface

Once the firmware has been loaded into the microcontroller, the unit will display the main menu after it's switched on. The screen shows several options, which you can navigate using the buttons.

The Up and Down buttons move the cursor, while the Enter button executes the selected menu command. From the main menu, you can start the scanner, adjust the display parameters, or show information about the CYWUSB6935 module and the firmware. If you change any of the display settings, such as the contrast, you can store the new settings in the microcontroller EEPROM so that they will be used automatically the next time.



Figure 5. Saw through the plastic substrate along the red lines marked on this photo.

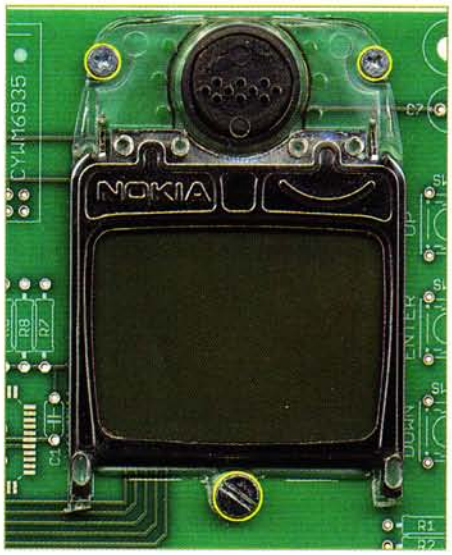


Figure 6. The display module is fitted to the PCB with two M2 screws and an M3 screw.

If you switch on the scanner while holding the Up button pressed, the display parameters are reset. If you hold the Enter button pressed while switching on the unit, the scanner enters the Contrast menu directly after it starts up, and you can then use the Up and Down buttons to adjust the contrast. The author has noticed that the standard display settings yield an unreadable result with some display modules.

The spectrum of the 2.4-GHz band is displayed in the scan mode. The frequency scale is indicated by tick marks directly below the spectrum plot. In most areas the ISM section of the 2.4-GHz band is divided into 84 channels from 2.4000 GHz to 2.4835 GHz, and the LCD module just happens to have 84 columns. The centre fre-

Links and References

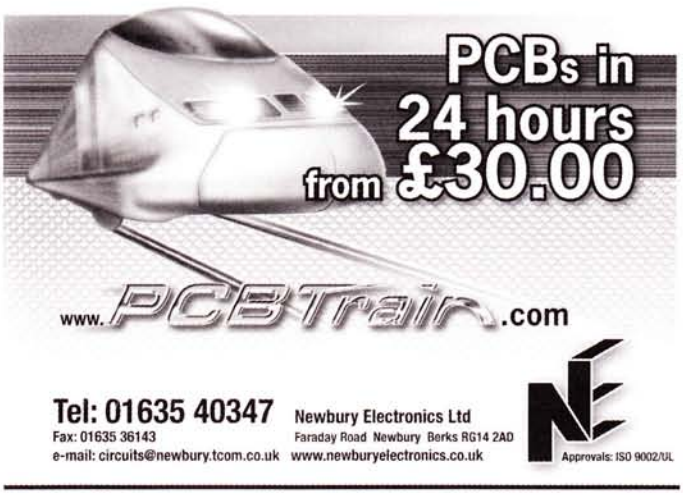
[1] Wireless links, Elektor January 2009

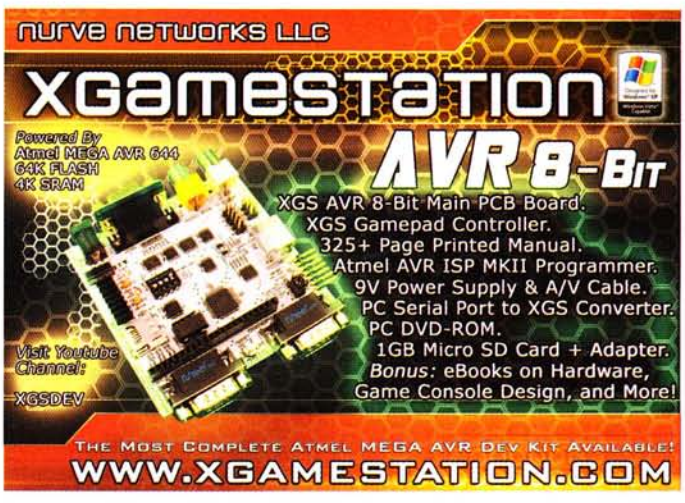
[2] 2.4 GHz WiFi Spectrum Analyser, Elektor June 2007

[3] Universal User Interface Module, Elektor December 2008

[4] www.elektor.com/090985

Advertisement





Menu Control

The main menu is pictured at the top here.

The Setup and About menu items each have a submenu.

The submenu 'Setup' has five options:

Use the first three menu items to adjust the contrast, bias, and temperature coefficient of the LCD module.

Use the EEPROM Store menu item to save the settings in the microcontroller EEPROM. When the scanner starts up, the saved values are read from the EEPROM and used to configure the LCD module.

The final menu item, Back, returns you to the main menu.

If you select About from the main menu, the following three options are displayed:

The Transceiver menu item shows information about the CYWUSB6935 module in the unit, including the unique manufacturing number:

The Firmware menu item shows the firmware version number.

If you select Scan in the main menu, scanning is started (lower picture):

The scanner starts up in Run mode, in which it constantly scans the entire 2.4-GHz band and shows the results on the LCD module. The maximum reading for each channel is saved and displayed. After a few seconds, you can easily see how the 2.4-GHz band is being used.

In the scan picture, you can see that WiFi band 1 is being used by a device that occupies approximately 20 channels. This is the author's wireless music player. You can also see a somewhat weaker signal in WiFi band 6. This is probably the wireless local network of one of the author's neighbours. In addition, a fairly strong continuous signal can be seen in channel 51. This is a narrowband signal, and it is constantly present. The author was not able to determine the origin of this signal.

There are no signals in the channels above channel 52. Here you can see the maximum noise floor level.

The scanner menu appears at the bottom of the screen. You can use the Up and Down buttons to navigate through this menu. Depending on the selected menu item, you can initiate an action or adjust a setting.

Use the first menu item to set the scan mode. It can have the values Run, Hold, and Off. Press Enter to select a different scan mode. This is indicated by displaying the selection in reverse video. Use the Up and Down buttons to select the desired setting.

Press Enter again to save the setting, after which you can continue navigating through the submenu.

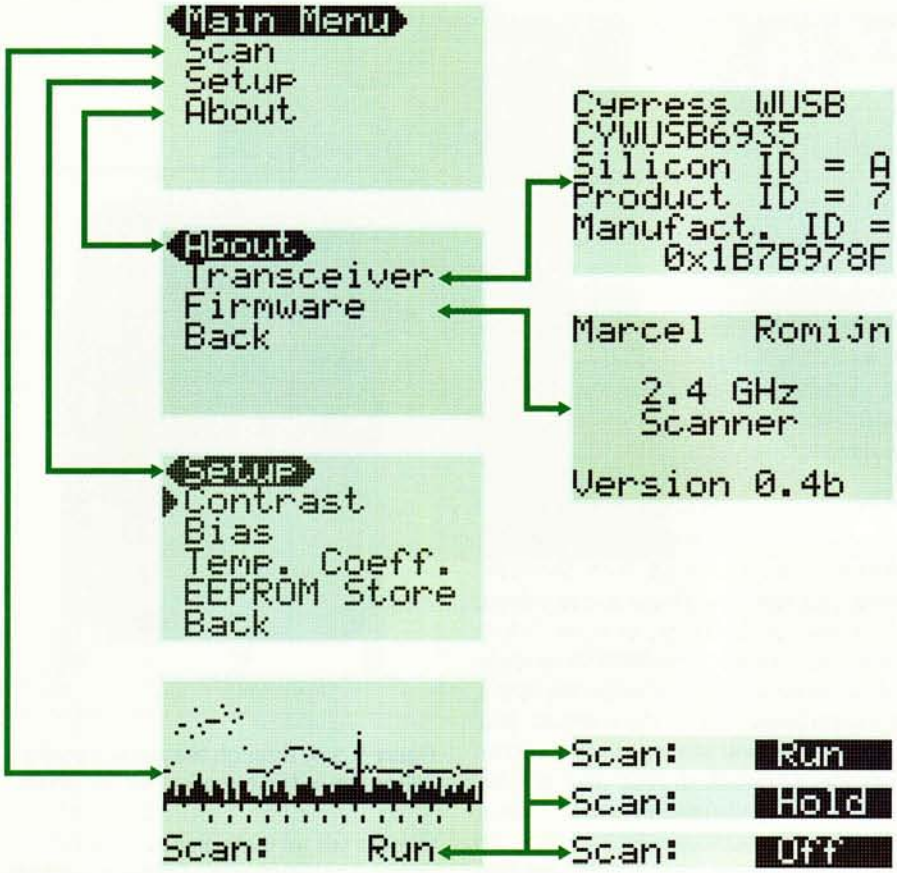
The next menu item controls whether the peak values (the 'limits') are shown (Show) or hidden (Hide).

Use the following menu item to reset the peak values. If you press Enter with this menu item selected, the peak values are reset immediately. This is a menu item that performs an action directly.

The following menu item indicates how many times each channel should be measured before the scanner switches to the next channel. The highest reading of the repeated measurements is used.

The next menu item is similar, but instead of indicating how many times the measurement is repeated for each channel, it indicates how many times the entire 2.4-GHz band should be scanned before the results are displayed.

The final menu item exits the scanner settings submenu and returns to the main menu.



quencies of the 13 WiFi channels are also indicated below the tick marks.

A single-line menu that can be used to set the scanning parameters is located at the bottom of the screen. Just as with the regular menu, the Up and Down buttons can be used to navigate through this menu, while the Enter button can be used to perform an action or set a value.

The menu interface is described in more detail in the Menu Control inset.

(090985)

Computer digital audio interface

By Joseph Kreutz (Germany)

Computer motherboards and lots of other computer devices are fitted with digital audio inputs and outputs in S/PDIF format, but which only produce or accept a TTL-level signal. Despite their undoubted usefulness, opto-interfaces are usually lacking. The project described in this article is intended to make up for this shortcoming.

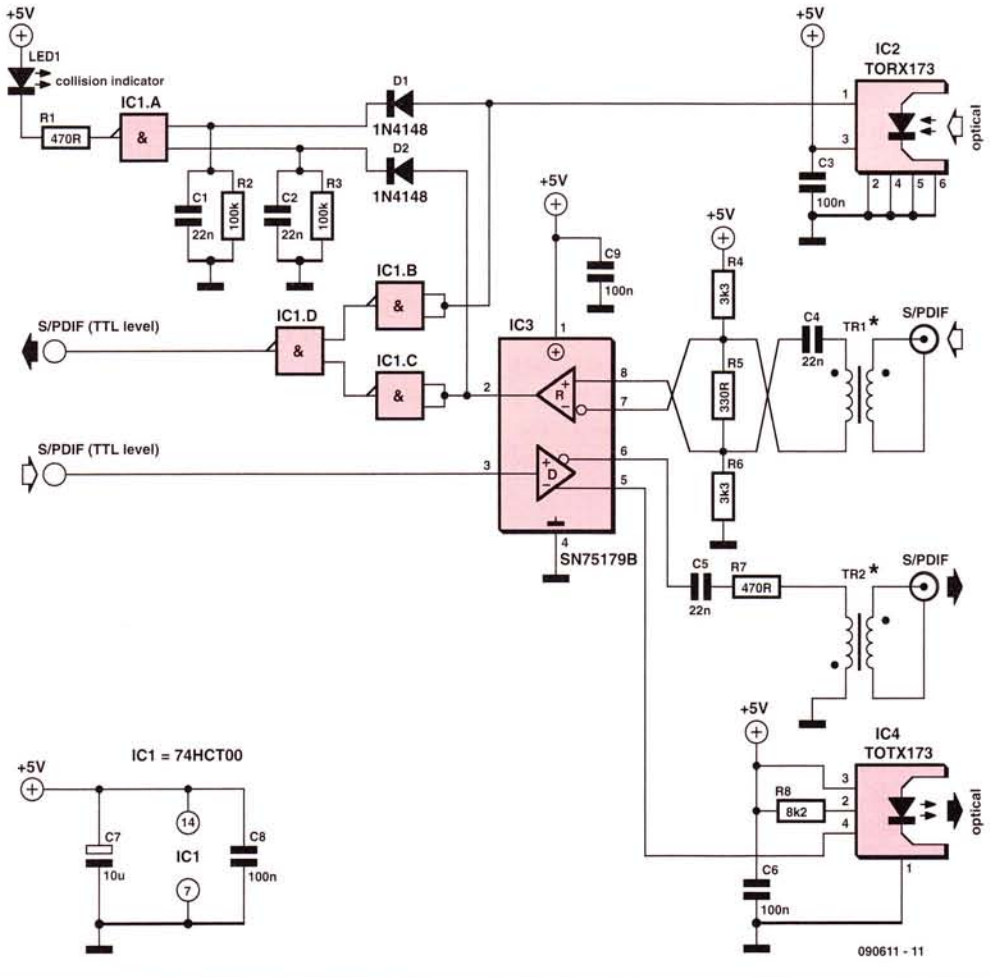
The receiving part comprises a transformer-isolated S/PDIF electrical interface, based on the receiving section of IC3, an SN75179B or equivalent differential driver/receiver. This part of the circuit is arranged in such a way as to produce a zero output signal if there is no input signal present. The opto receiver IC2 is a TORX173. Logic gates IC1b to IC1d are wired to form an OR gate to steer the signals to the TTL output, from where they will be applied to the equipment intended to receive them. Needless to say, the optical and electrical input can't both be used at the same time, since otherwise it would be impossible to decode and use the signals. The function of IC1a, along with D1, D2, and the R2/C1 and R3/C2 networks, is to indicate if such an error condition arises, in which case the LED lights to indicate the problem.

Transformer TR1 is hardly difficult to make: a primary of six turns of enamelled wire (0.3–0.5 mm dia.; AWG # 28–24) and a secondary of 12 turns of the same wire are wound onto an Epcos L44-X830 ferrite ring (12.5 mm dia.). Any ferrite ring with α = 2200 nH/√turn will do.

The TTL signal from the computer device is applied to the driver section of IC3. The inverting output is applied to transformer TR2 via C6 and R7. TR2 uses the same ferrite ring as TR1, but has 20 turns for the primary and eight for the secondary. You'll need to make sure you connect its primary in reverse phase, to make up for the signal inversion introduced by IC3. The non-inverting output of IC3's driver section is connected to a TOTX173 opto-transmitter. Naturally, there's no problem at all about using the electrical and optical digital outputs at the same time.

Building this circuit requires no special comments. Each IC needs to be decoupled by a 0.1 µF capacitor as close as possible to its supply pins, and overall decoupling of the circuit at lower frequencies will be taken care of by a 10 µF, 16 V electrolytic capacitor. The 5 V supply rail can be derived from the computer equipment where the interface is going to be installed.

(090611-I)



Blinded by the Light?
Lamp PFC investigated

By Ton Giesberts (Elektor Labs) & Clemens Valens (Elektor France)

When the load of a power supply is not purely resistive but reactive, or worse, non linear, the current through the load may not have the same shape as the voltage across it, and a phase difference between voltage and current will exist. In this case the apparent power drawn by the load is larger than the real or active power consumed by it. The ratio between the real power and the apparent power is called the power factor. When its value drops too low, problems arise.



A low power factor is a problem for energy providers, not the users, because they only pay the real power consumed. Energy providers have to assure that their power supply systems are capable of safely providing the total apparent power demand of all users. Since the apparent power is always higher than the real power, the supply system (AC grid) has to be over dimensioned, which is expensive. More power also means higher losses in the form of heat and consequently more resources are necessary to produce the real power. Non-linear loads also create harmonics that produce excess heat and may cause interference in other equipment. It should be clear by now; we want a power factor of 1 (say, one), i.e. apparent power should equal real power.

High volume energy users like industrial plants actually have to pay for the apparent power they use but households generally don't. Industrial users sometimes install special equipment to control their power factor striving to approach the value 1. This is called power factor correction (PFC). The European standard IEC 61000-3-2 [1] sets detailed limits for a consumer (not professional) load up to and including 16 A per phase connected to the public AC grid. **Table 1** shows the subdivision into four classes A, B, C and D of which the last two are the most interesting to us. All electrical equipment marketed to European consumers must comply with this standard.

Linear and non-linear loads

Most loads are not purely resistive. Incandescent light bulbs are, but as soon as there is a bit more involved the load becomes a complex impedance. Many loads have motors and these are typically inductive loads. That's why the real current usually lags the line voltage. The phase difference, often called phi (φ in Greek), between the current and the voltage is a measure for the power factor. As a matter of fact, when the current and the load are both perfect sine waves then the power factor is simply equal to cos(φ) (**Figure 1**). This is why the power factor is also called cos phi, even though this is incorrect when the wave shapes involved are not perfect sines. But when they are, the power factor can be corrected by adding a capacitor (or banks of them) in parallel with the load, and that's exactly what professional users sometimes do. Thanks to the capacitors they keep their energy bills down.

Today, electrical loads are becoming increasingly more complex and many have even gone non-linear, i.e. the current is no longer a linear function of the AC grid voltage. This happens as soon as rectifiers and switched mode power supplies enter the arena, which is the case for most of our modern household electronics like computers, TV sets, fluorescent lighting and LED light bulbs, etc. Non-linear currents have harmonics that can cause problems when capacitors are used to improve the power factor. In certain cases the harmonics in combination with these capacitors may result in resonances producing overvoltage situations and heat, potentially damaging equipment.
Power factor correction of non-linear loads requires other techniques than simply adding a capacitor to the load. It can be done passively with (bulky) filters that suppress the harmonics produced by the load. Another approach is active PFC, a method that adds electronics circuitry to the load to make it look more passive.

Measuring the power factor

To measure a load's power factor you need to measure the real or active power with a wattmeter and the effective load current I_{rms} and the effective voltage V_{rms} across the load. The product $I_{rms} \times V_{rms}$. is the apparent power and the power factor *PF* is the real power divided by the apparent power. Most people do not have the necessary equipment to measure these quantities properly and besides it's a dangerous operation if you cannot isolate the load from the AC power lines.

Elektor labs have done some measurements of Class C equipment (lighting) using the circuit from **Figure 2**. A variac (variable transformer) was used to isolate the load from the AC power line and a 100:1 oscilloscope probe (special high-voltage version) was used to measure the voltage at the load. The 10 Ω resistor was a 5 W type. If you do not have these tools, please do not try to repeat our measurements, **it can be lethal!**



Our oscilloscope was a LeCroy 9410 capable of displaying in real time the Fourier series (magnitude and phase) of one of the traces. We used that feature on the current measurements to visualise the harmonics. In all experiments I_{rms} was measured with a Fluke 187 true rms multimeter.

Some real measurements

To illustrate the effect of a load on the power factor we first measured a traditional incandescent 100 watt light bulb. This is a pure resistive load and the *PF* should be 1. **Figure 3** shows the results: the current is perfectly in phase with the voltage and has the same shape; it is indeed a resistive load hence *PF* = 1. Note that the phase trace shows two peaks for the third and seventh harmonic, even though the magnitudes of these harmonics are very small. The reason is the distortion of the AC power line voltage wave shape which is not a perfect sine wave at all.

Next we measured a fluorescent tube (36 W TL-D made by Philips). The traces in **Figure 4** show a reactive load, although not perfect as the current wave shape is clearly distorted around the zero crossings. The Fourier traces show a clear third harmonic and a small fifth. Nevertheless, the current is very reactive and may be corrected with a capacitor (which was absent in our test setup). Ignoring the harmonics the *PF* for this tube is about 0.5 because the phase difference between the current and the voltage is about 60° and cos(60) = 0.5.

When we started measuring on compact fluorescent lamps (CFLs), also known as energy saving lights, things became more interesting. We looked at three different models, two recent ones (a Philips PLE-C PRO 11 W and an unknown 11 W model found in a product from a well-known Swedish furniture manufacturer) and a several years old but still working lamp (20 W Isotronic 10112). **Figures 5** to **7** show the results that look surprisingly similar and strange at the same time. These wave shapes are typical for these kinds of lights and show their switching nature.



Determining the power factor from such traces is difficult unless you have access to the Fourier series that goes with them. The trick is to first determine the effective value of the in-phase fundamental frequency of the current and then divide it by the measured effective current I_{rms}. For the Philips PLE-C the magnitude of the fundamental is about 700 mV across 10 Ω with a phase difference of 20 degrees. Hence, the in-phase current is (700 mV/10 Ω) × cos(20) = 66 mA and its effective value is 66 mA/√2 = 47 mA. The I_{rms} value we measured for this lamp was 67 mA, which gives us a *PF* of 0.70 for this lamp. Similar reasoning gives us a *PF* of 81/107 = 0.76 for the Isotronic bulb and 56/76 = 0.73 for the Ikea lamp.

From the CFL to the LED lamp is just a small step. The LED lamp is making big progress in market share (in quality too, but not as spectacular) and many of you will have one or more at home. The

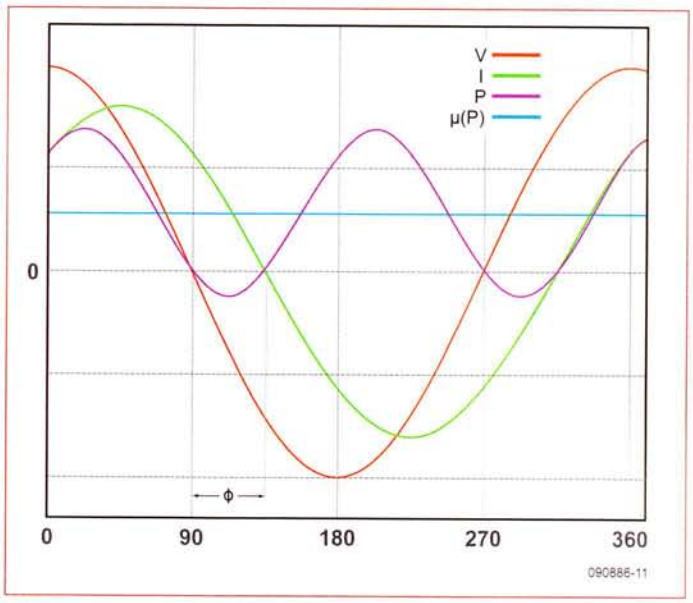


Figure 1. The relation between voltage, current and power factor Φ. $P = VI$ and $\mu(P)$ is the average value of the power P. (source: Wikipedia)

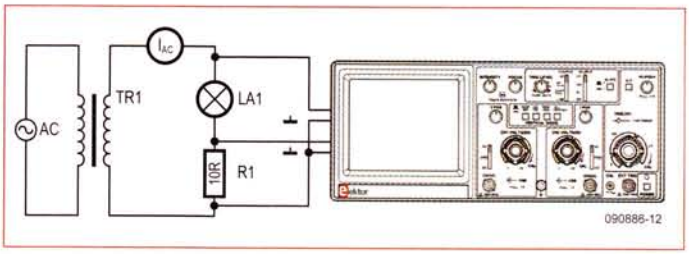


Figure 2. Experimental setup to determine some power factors.

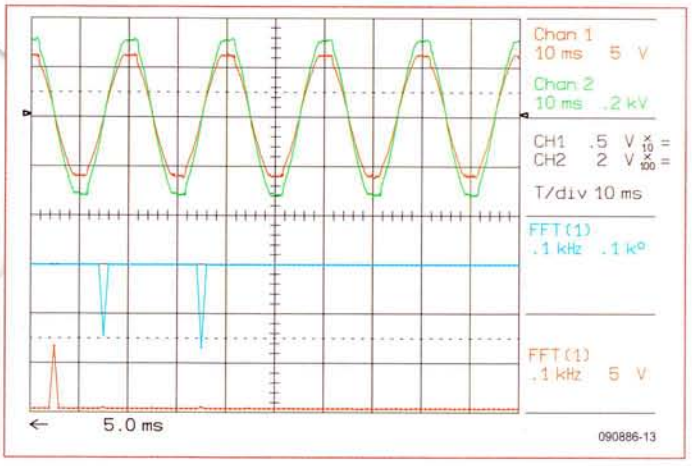


Figure 3. Results from a 100 W incandescent lamp. This was a 220 V model and the measured I_{rms} was 440 mA.

Table 1. Equipment classification

Class	Description
A	Balanced three-phase equipment; household appliances, excluding equipment identified as class D; tools, excluding portable tools; dimmers for incandescent lamps; audio equipment. Equipment not specified in one of the three other classes shall be considered as class A equipment.
B	Portable tools, arc welding equipment which is not professional equipment. (Professional equipment is equipment not available to the consumer.)
C	Lighting equipment.
D	Equipment having a specified power less than or equal to 600 W, of the following types: personal computers and personal computer monitors; television receivers.

Source: IEC 61000-3-2

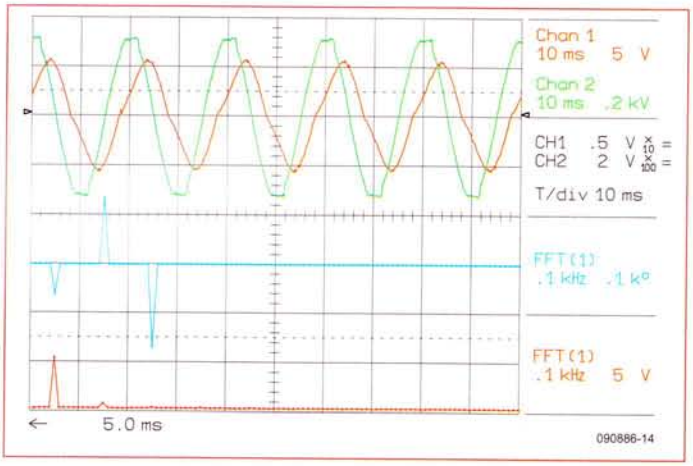


Figure 4. A reactive load in the form of a 36 W fluorescent tube; cos(Φ) = 0.5. I_{rms} = 352 mA.

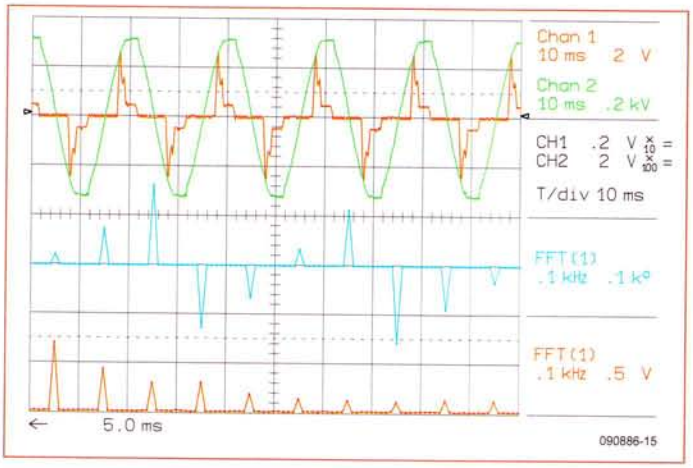


Figure 5. An 11 W PLE-C PRO CFL from Philips. I_{rms} = 67 mA.

traces in **Figures 8** and **9** show the results for two models we had lying around, a monochrome one and a three-colour lamp with individual remotely controllable colours. These lamps were both from that widely known brand called "Made in China".

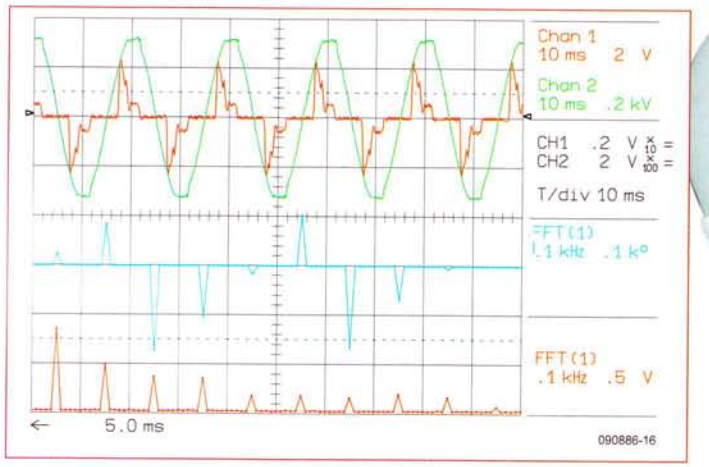


Figure 6. As Figure 5, but now for the Ikea lamp. I_{rms} = 76 mA.



The current traces are very spiky, due to the little bit of power consumed by these lamps, but they result in a very wide spectrum. For these lamps, $PF = 20/34 = 0.59$ (monochrome) and $12/28 = 0.43$ (three-colour).

Do they pass?

IEC 61000-3-2 subdivides lighting equipment (Class C) into devices consuming up to and including 25 W and those that consume more. For both subclasses maximum figures have been set for harmonic currents, see **Table 2**.

The three CFL lamps and the two LED lamps examined in the lab all have strong harmonics, most of which do not respect the values in the third column of Table 2. Should we therefore conclude that these lamps are illegal on the European market? Probably not, as there is a second clause for lamps that consume up to and including 25 W — see (and try to

Table 2. Limits for class C equipment

	Maximum permissible harmonic current		
Harmonic order	**Active input power > 25 W**	**Active input power ≤ 25 W**	
n	% of input current at fundamental frequency	mA/W	The third harmonic current, expressed as a percentage of the fundamental current, shall not exceed 86 % and the fifth shall not exceed 61 %; moreover, the waveform of the input current shall be such that it begins to flow before or at 60°, has its last peak (if there are several peaks per half period) before or at 65° and does not stop flowing before 90°, where the zero crossing of the fundamental supply voltage is assumed to be at 0°.
2	2	-	
3	30 × power factor	3.4	
5	10	1.9	
7	7	1.0	
9	5	0.5	
11	3	0.35	
13 ≤ n ≤ 39 (odd harmonics only)	3	3.85/n	

Source: IEC 61000-3-2

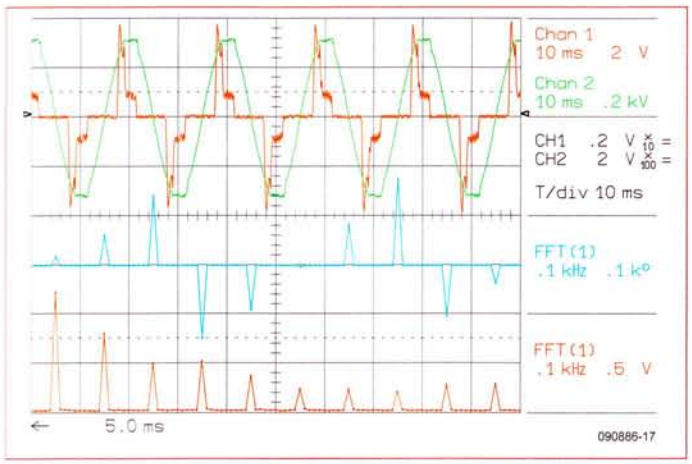


Figure 7. Similar to Figures 5 and 6; data obtained from an old 20 W Isotronic CFL. I_{rms} = 107 mA.

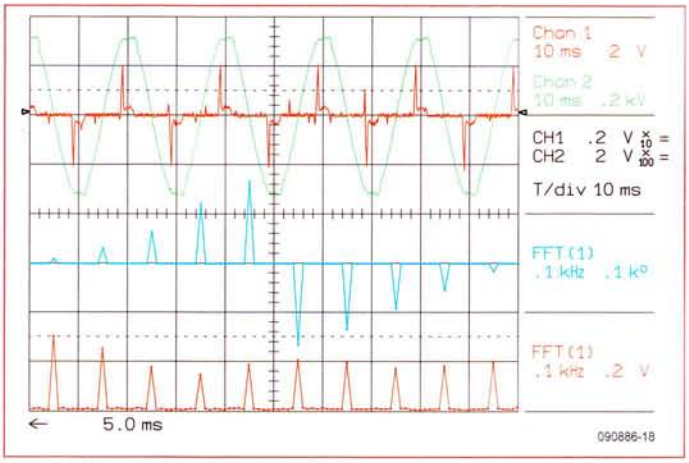
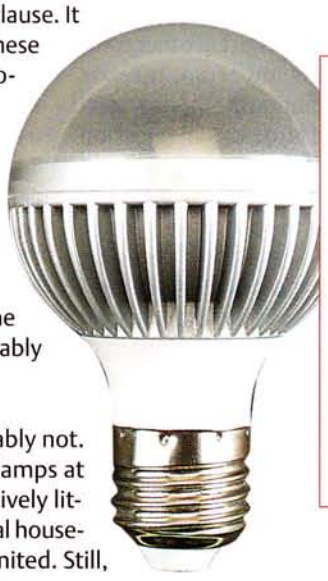


Figure 8. This el-cheapo monochrome LED lamp exhibits an almost flat current spectrum yet seems to be conform to IEC 61000-3-2. I_{rms} = 34 mA.

understand) the fourth column of Table 2. This clause only mentions harmonics three and five and allows much higher values, so our lamps probably all pass thanks to this clause. It makes you wonder about the point of these clauses, as it actually seems hard to produce something non-compliant.
Also, the lab measurements did not respect the test conditions specified in IEC 61000-3-2 and admittedly instruments were not carefully calibrated; we just did some quick and dirty measurements using the available AC power line with noise and all. Yet the results are surprising and they are probably not that far off the mark.



Should you worry about all this? Probably not. Even if you light ten or more of these lamps at the same time, you still consume relatively little power and their influence on the total household power factor is likely to remain limited. Still, you are polluting the AC power line voltage.

(090866-I)

[1] IEC 61000-3-2 2005-11 (third edition). www.iec.ch

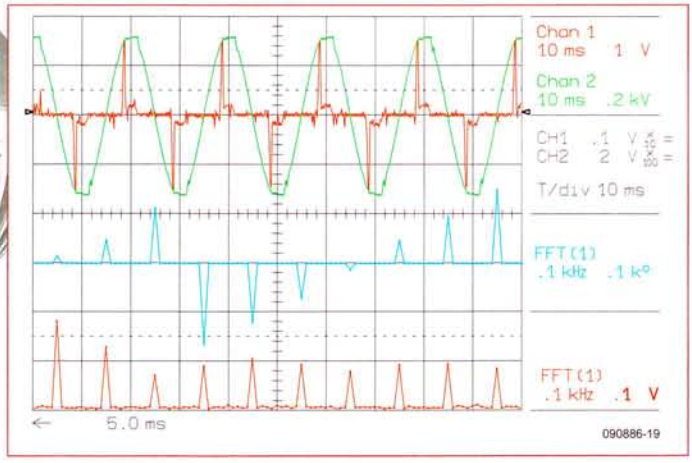
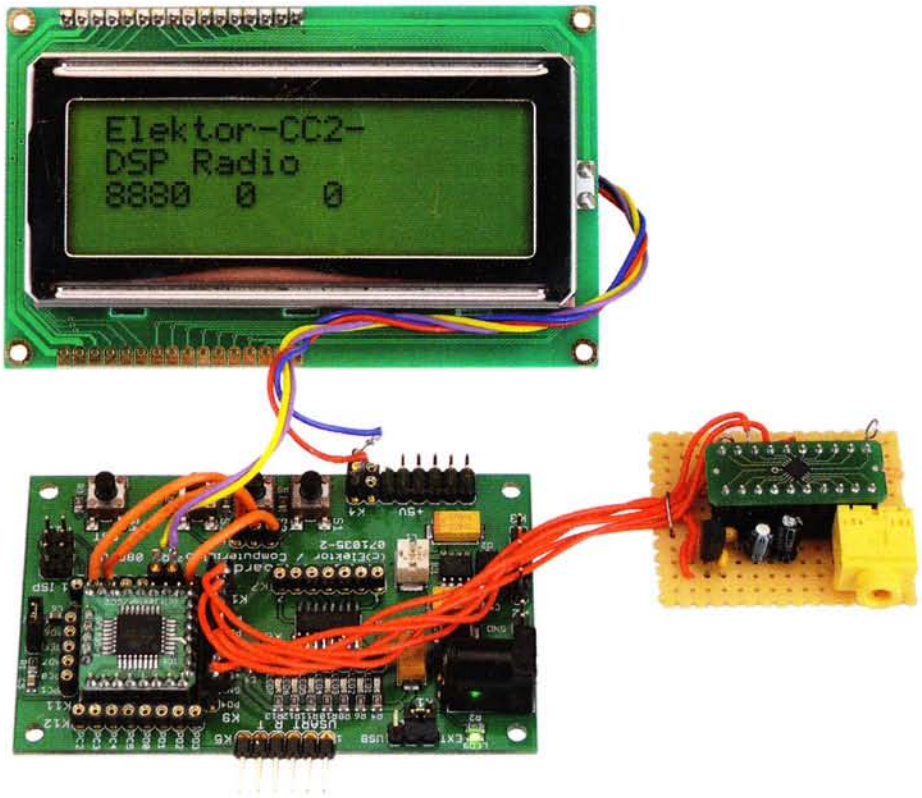


Figure 9. The spectrum of the remote controlled three colour LED lamp is as bad as the one of the LED lamp from Figure 8. I_{rms} = 28 mA.

The ATM18 Radio Computer

Using the SI4735 DSP radio chip

By Burkhard Kainka and
Wolfgang Rudolph (Germany)



Once upon a time radio reception was so simple. You just needed three components and a set of headphones. Best reception was after sundown, with an aerial stretching the length of the garden and a little patience you could pull in lots of stations. Nowadays you can do a similar job using the computing power of thousands of transistors crammed into a tiny chip.

One of the earliest types of radio receiver was the detector receiver. A coil together with a variable capacitor took care of frequency selection. A small chunk of crystal that you might dig up in your back garden served as a signal rectifier. Hook up a long wire out of the window for the aerial, add a set of high impedance headphones (2 x 2,000 Ω) and you were in business. In those days it was the cutting edge of technology. In time the crystal detector was superseded by the more reliable diode. Gone were the days of probing the crystal surface with the tip of a fine wire (cat's whisker) to find a defect in the crystal lattice where the best rectifier effect was produced. In time valves made way for transistors and radio front-ends eventually became populated by high frequency RF transistors. A big leap in radio performance came about at the introduction of the highly sensitive superhet radio which was not improved upon for many years. Also the complex method of signal conversion using one or more intermediate frequencies remained unchanged. A classic radio design of this era used coils, variable capacitors, IF filters and a host of other components. Many of the important receiver properties such as spurious response rejection, selectivity and large-signal rejection etc depend largely on the type of filters used in the design. With increasingly sophisticated technology all the processes such as AM and FM demodulation, stereo decoding and RDS information recovery were performed by highly-integrated specialised chips. Eventually we saw the introduction of one-chip radios, first for AM and then later FM so that when we set out to build a radio using these components there was hardly any building left to do.

A Software Radio

More recently came the idea of a Software Defined Radio (SDR). This was a completely new concept which had little in common with traditional radio design. SDR uses computer software to carry out the functions usually performed by the receiver hardware. Receiver parameters can be changed 'on the fly' with minimum time delay and almost at will. We have already shown in Elektor what's achievable in a Software-defined-Radio design. With the hardware reduced to a minimum you will find no conventional RF components on the PCB. The intermediate frequency (IF) is digitised by the computer sound card for further processing. The SDR program running on a computer takes care of the rest. Adjustable bandwidth, different demodulation techniques, automatic level control, in fact there are very few parameters that cannot be altered. At the end of the chain a D/A converter in the sound card outputs the demodulated audio to a set of active speakers.

DSP Radio

While the first wave of SDRs were defined

Main features of the SI4735

- VHF range: 64–108 MHz
- LW range: 153–279 kHz
- MW range: 520–1710 kHz
- SW range: 2.3–21.85 MHz
- PLL with integrated VCO
- Automatic frequency control (AFC)
- Automatic gain control (AGC)
- Integrated LDO voltage regulator
- Digital FM stereo decoder
- Programmable reference frequency
- Digital volume control
- RDS support
- Optional digital audio output
- 2 or 3 wire interface
- Supply voltage 3.3 V typ.
- Outline 3 x 3 x 0.55 (mm), 20 pin QFN



Figure 1. The 3 mm x 3 mm radio.

(as the name suggests) in software i.e. from a program running in a computer so the more recent wave of digital radio chips have appeared which do not use a computer and are therefore not really SDRs in the original sense of the term. Processing of the receive signal is performed in the chip using a digital signal processor (DSP). The external controller just interprets user commands and tells the radio chip what it should do. As an extreme example of this concept we see here a 3 mm x 3 mm chip which just requires an aerial, a power supply and two active speakers to make a stereo VHF receiver. Very little additional hardware is required, a coil and a capacitor are all that are necessary for VHF reception. We will use the Elektor ATM18 AVR board as the controller for the radio.

DSP ICs operating at RF are usually thought of as expensive and power hungry beasts but that cannot be said of the SI4735 from Silicon Labs (www.silabs.com). This is a DSP receiver containing all the necessary RF stages; frequency synthesizer, A/D converter, DSP and D/A converter all squashed into a tiny SMD package! The chip shown in Figure 1 is a complete AM/FM receiver. The AM band extends from 153 kHz (Long wave) up to 21.85 MHz (13-m short wave band), with switchable bandwidth filters and a particularly sophisticated gain control section. VHF reception covers the 64 MHz to 108 MHz band with an integrated stereo decoder and RDS output. The chip also supplies information indicating signal strength (RSSI) in dBµV and signal-to-noise ratio (SNR) in dB of the received signal. The SI4735 could be used as a RF signal level measurement receiver.

The chip has a good specification which makes it ideal for use in the design of travel radios, clock radios or MP3 players and mobile telephones which are now increasingly being offered with built-in radio receivers. The first travel radio design featuring DSP chips from SI is already available. The object of the exercise here of course is not to buy a ready built radio but to find out just how easy it is to make our own. First off we need some form of microcontroller to allow input of data to the chip and which can display information such as receive frequency, volume etc. This is where our ATM18 AVR board comes in, together with the SI4735 we can build a really versatile receiver with very little additional outlay.

The block diagram of the chip in Figure 2 shows the layout of a typical IQ type of receiver, similar to that which was used in our shortwave receiver. In this case however the signal decoding is performed not by external PC software but via a DSP built-in to the chip. An external microcontroller acts as a control interface with the user.

Interface to the ATM18 AVR board

You will only need a few hook-up wires to connect the supply voltage, reset signal and I²C Bus from the ATM18 AVR board to the radio board before you have a fully functioning VHF receiver. The IC produces a surprisingly good audio output signal and the receiver stage has good sensitivity even with a short antenna. The only additional stage necessary is a stereo amplifier. A set of active speakers such as those used on a PC will do. Those of you wishing to tune in to AM broadcasts can do so later by just making a few simple changes to the receiver.

The chip is supplied in a QFN outline package which is so tiny it is difficult to solder. The solution is to use a carrier board with the chip pre-mounted (Figure 3). The carrier has the same footprint as a 20-pin DIP IC so it can either be mounted using a cor-

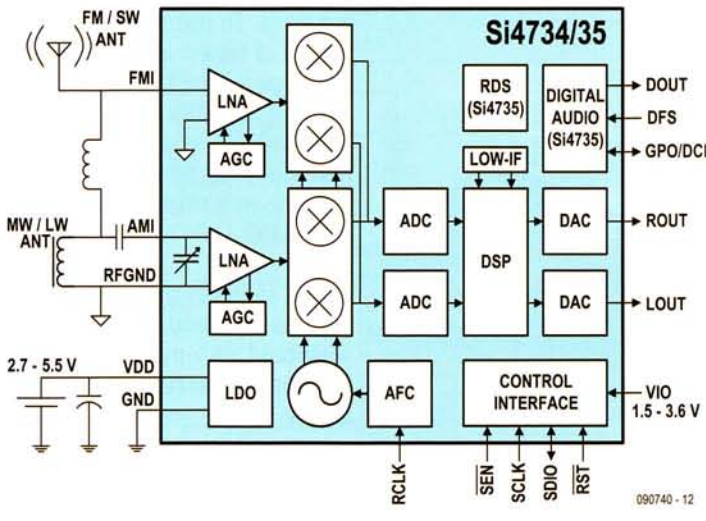


Figure 2.The SI4735 block diagram (source : www.silabs.com).

Listing 1. Initialisation and setup

```
Config Timer0 = Pwm , Prescale = 1 , Compare A
   Pwm = Clear Down
Start Timer0
Pwm0a = 128 'Xtal/2/(255) = 31373 Hz OC0A/ PD6

Ddrd.4 = 1              'Reset SI4735
Waitms 100
Ddrd.4 = 0
Waitms 100

Ffm = 8880          'Start freq  FM *10 kHz
Vol = 63            'Volume 0...63
...

Sub Fm_start()
  Init_fm
  Waitms 200
  Refclock
  Waitms 5
  Rx_volume
  Waitms 5
  Fm_tune_freq
End Sub

Sub Init_fm()
  I2cstart
  I2cwbyte 34
  I2cwbyte &H01
  I2cwbyte &H00
  I2cwbyte &H05
  I2cstop
End Sub

Sub Refclock()
  I2cstart
  I2cwbyte 34
  I2cwbyte &H12
  I2cwbyte &H00
  I2cwbyte &H02
  I2cwbyte &H01
  Ref = 31373
  H = High(ref)
  L = Low(ref)
  I2cwbyte H
  I2cwbyte L
  I2cstop
End Sub

Sub Fm_tune_freq();
  I2cstart
  I2cwbyte 34
  I2cwbyte &H20
  I2cwbyte &H00
  H = High(ffm)
  L = Low(ffm)
  I2cwbyte H
  I2cwbyte L
  I2cwbyte &H00
  I2cstop
End Sub

Sub Rx_volume()
  I2cstart
  I2cwbyte 34
  I2cwbyte &H12
  I2cwbyte &H00
  I2cwbyte &H40
  I2cwbyte &H00
  I2cwbyte &H00
  I2cwbyte Vol
  I2cstop
End Sub
```

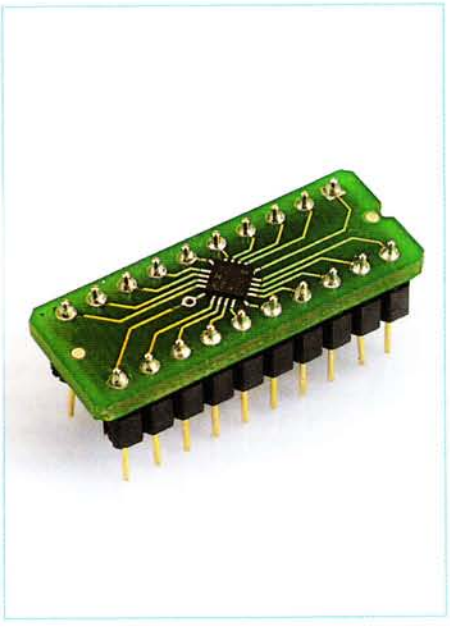


Figure 3.
The SI4735 is soldered to a carrier board.

responding socket or by just soldering flying leads. To complete the receiver circuit shown in Figure 4 you need to add a few resistors, a fixed inductor and two diodes. The two Schottky diodes protect the input from large RF impulses so are not strictly necessary for operation. The circuit can be built on a small square of prototyping perfboard.

The IC requires a supply voltage of 3.3 V on pins VDD and VIO. NB: VDD can only withstand 3.6 V maximum! Make sure that it is not accidentally connected to the 5 V supply.

The SI4735 has a number of digital interfaces but the one we are using here is the I²C bus. This requires just two wires, one for SDA and one for SCL. These carry commands to the IC and receive status information back from the IC to the ATM18 AVR board (ATmega88). In addition a connection to the IC's reset input is necessary with a pull-up resistor to the 3.3 V. This acts as a level shifter when the port output of the ATM18 AVR board is switched between high impedance (High) and low impedance (Low), this is normal practice for the I²C bus signals.

Apart from this the receiver needs a clock to use as a tuning reference. A 32.768 kHz watch crystal is typically used here but the chip can accommodate other frequencies. The value of the reference clock is sent to the chip during initialisation. Its minimum value is 31.130 kHz and maximum is

Listing 2. Station search and Status display

```
Sub Fm_seek_freq_up()
  I2cstart
  I2cwbyte 34
  I2cwbyte &H21
  I2cwbyte &H0C
  I2cstop
End Sub


Sub Fm_seek_freq_down()
  I2cstart
  I2cwbyte 34
  I2cwbyte &H21
  I2cwbyte &H04
  I2cstop
End Sub

Sub Fm_tune_status()
  I2cstart
  I2cwbyte 34
  I2cwbyte &H22
  I2cwbyte &H3
  I2cstop
  I2cstart
  I2cwbyte 35
  I2crbyte Status , Ack
  I2crbyte R1 , Ack
  I2crbyte R2 , Ack
  I2crbyte R3 , Ack
  I2crbyte R4 , Ack
  I2crbyte R5 , Ack
  I2crbyte R6 , Ack
  I2crbyte R7 , Nack
  I2cstop
  Freq = 256 * R2
  Freq = Freq + R3
  Rssi = R4
  Snr = R5
  Lcdpos = 2 : Lcdline = 3 : Lcd_pos
  Lcdtext = Str(freq) + " " : Lcd_text
  Lcdpos = 8 : Lcdline = 3 : Lcd_pos
  Lcdtext = Str(rssi) + " " : Lcd_text
  Lcdpos = 12 : Lcdline = 3 : Lcd_pos
  Lcdtext = Str(snr ) + " " : Lcd_text
End Sub

Sub Fm_rsq_status()
  I2cstart
  I2cwbyte 34
  I2cwbyte &H23
  I2cwbyte &H00
  I2cstop
  I2cstart
  I2cwbyte 35
  I2crbyte Status , Ack
  I2crbyte R1 , Ack
  I2crbyte R2 , Ack
  I2crbyte R3 , Ack
  I2crbyte R4 , Ack
  I2crbyte R5 , Ack
  I2crbyte R6 , Ack
  I2crbyte R7 , Nack
  I2cstop
  Rssi = R4
  Snr = R5
  Lcdpos = 8 : Lcdline = 3 : Lcd_pos
  Lcdtext = Str(rssi) + " " : Lcd_text
  Lcdpos = 12 : Lcdline = 3 : Lcd_pos
  Lcdtext = Str(snr ) + " " : Lcd_text
End Sub
```

40 MHz, built-in dividers are used to generate a 32 KHz (approx) internal clock. It should be noted that overtones generated by higher frequency inputs can adversely affect the receiver performance so for this reason a reference clock of approximately 32 KHz was chosen. The ATmega88 has no problem generating it from one of its PWM outputs. Accuracy and stability of receiver tuning is therefore ultimately referenced back to the 16 MHz crystal used in the ATM18 AVR board.

The ATM18 AVR board also interfaces to an LC display using the signals from B1 and B2. Three pushbuttons are also wired to B0, B3

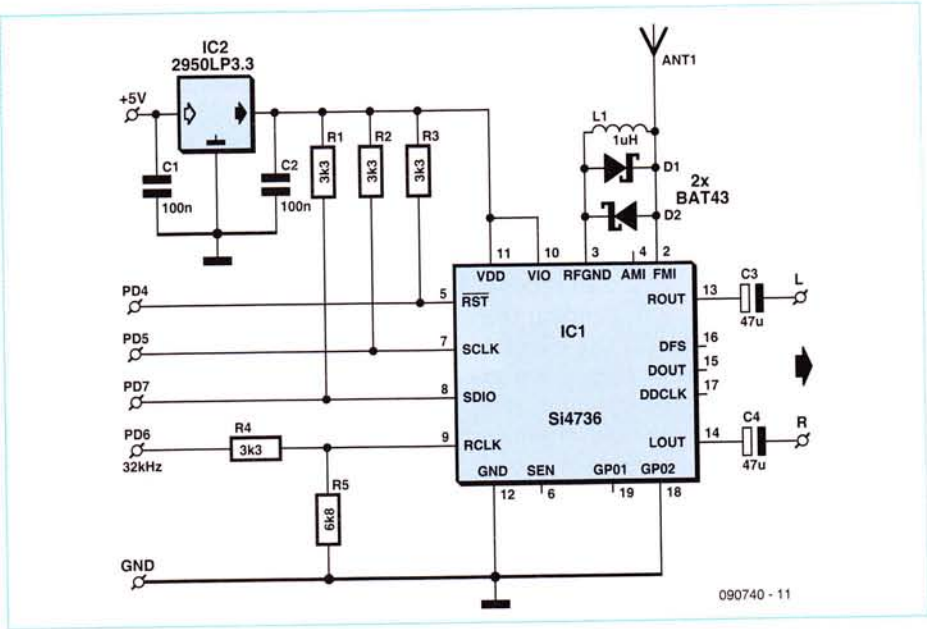


Figure 4.
The radio module connections to the ATM18 AVR board.

Detector

Even before diodes became commercially available it was possible to rectify HF signals using a type of envelope detector which can detect amplitude modulated RF signals. Firstly a small fragment of either galena (lead sulphide) or iron pyrite crystal is necessary. This crystal is held in a metal clamp which also serves as one electrical connection for this rudimentary 'diode'. The other connection takes the form of a thin pointed wire pressed lightly against the crystal surface (often with the help of a light spring). The tip is moved over the crystal surface by hand to find a 'point defect'. This is a spot in the crystal where a vacancy or pair of vacancies has occurred in the crystal lattice.

This 'Schottky defect' as it became known indicates that the crystal detector was actually an early variant of the Schottky diode.

Naturally this 'defect' works just as well today for AM broadcasts as it did back at the dawn of the radio age and it shouldn't be too difficult to find a suitable crystal, they occur quite commonly in nature. It would make an interesting diversion and an electronic trip back in time to build such a set which after all is the root of all modern day radio sets.

and B4 these allow the following functions to be selected on the radio:

S1 to PortB.0: scan, short press scans upwards longer press scans downwards.
S2 to PortB.3: loudspeaker –
S3 to PortB.4: loudspeaker +

The display shows the receive frequency, signal level and signal to noise ratio.

Software

The software to control the radio chip is written in BASCOM. Listing 1 shows part of the software which takes care of initialising and chip set-up. After Start the SI4735 requires a reset pulse which is performed by DDRD.4 of the data direction register. This port pulls the reset pin momentarily low and then releases it. After reset the chip is ready for communication over the I²C bus. Its I²C address is 34.

The SI4735 is now initialised to receive either FM or AM signals by sending the corresponding commands. The Init_FM subroutine defines the analogue stereo output and the external clock input. The ATmega88 generates the clock from its PWM output A from Timer 0. The clock has a frequency of 31.373 Hz and this information is provided in the RefClock subroutine so that the radio can calculate the divisor. Using FM-Tune-Freq the desired frequency is represented as a multiple of 10 KHz so that 88.8 MHz is sent as 8880.
That is basically all that is required to get the receiver up and running. The output volume level can also be defined and this will be given a value in the range of 0 to 63.
The start frequency is given as 88.8 MHz. This can be changed to any other desired frequency. In operation it is necessary to use the internal 'station search' (Listing 2) procedure to change the received station. A short press of pushbutton S1 will call Fm_seek_freq_up searching upwards for a station, while a long press calls Fm_seek_freq_down to search downwards.



Figure 5. Status display on the LCD.

The frequency of the new station is read by using Fm_tune_status. In addition there are other internal registers which store more information. Especially interesting is the signal strength (RSSI) and signal to noise ratio (SNR) of the received signal. These values are written to the display when the new station is found (Figure 5). Once on-station it isn't necessary to change the frequency display but signal strength will vary so by periodically calling Fm_rsq_status the most recent receive signal parameters are fetched and sent to the display.

Work in progress

Looking at the versatility of this chip it really would be difficult to make use of every one of its features in any single application. With a bit of imagination you could use this chip in radio designs and experiment with totally different user interfaces. How about a single-button concept using a pot or rotary encoder? Direct frequency input is possible as well as station presets. A timer controlled radio will make sure you don't miss any of your favourite programmes. The RDS capability of the SI4735 also allows the display of station identification, radio text information, time of day and much more provided that the necessary software is in place to decode the information.
It's remarkable that advances in technology at one time took all the thinking work out of radio set construction or at least made the process much less interesting. Now with the versatility of a device like the SI4735 we are faced with a whole different set of challenges and it's suddenly become interesting again.

(090740)

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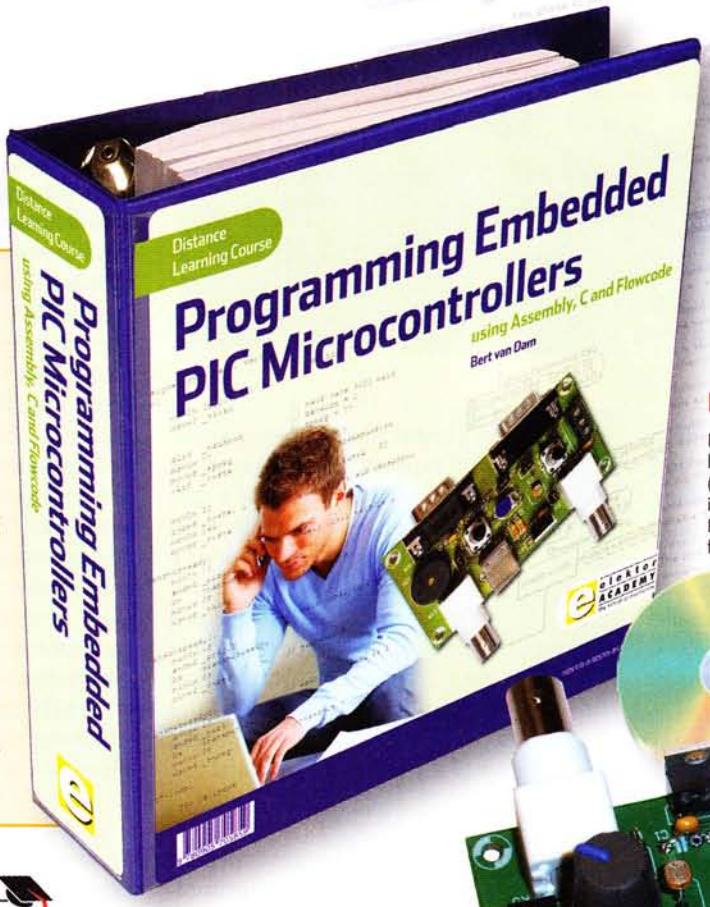
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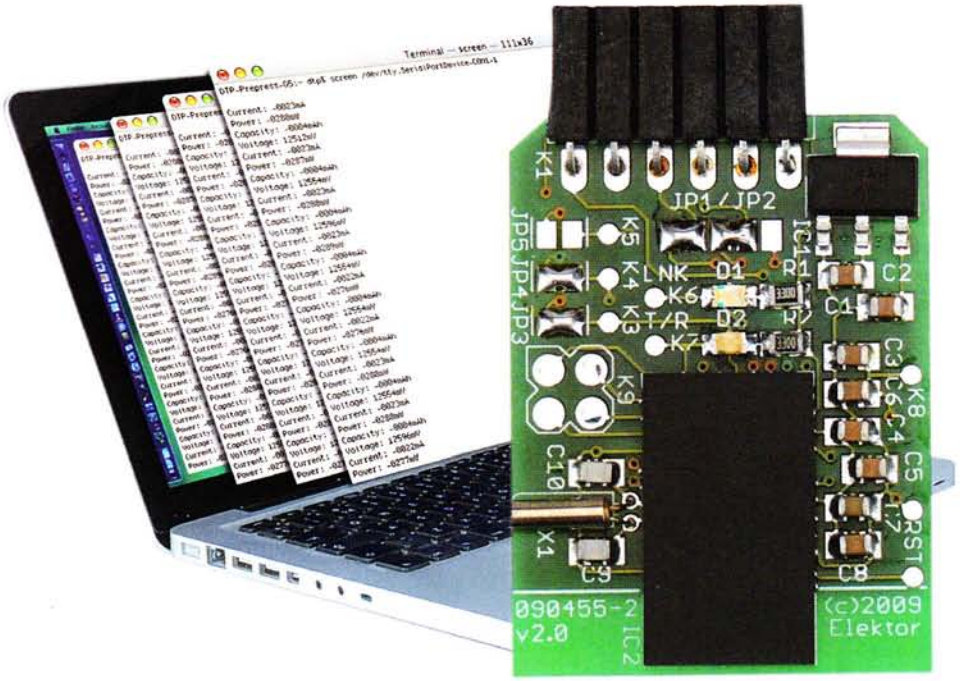
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TTL Bluetooth Dongle

Wireless data comms made easy

By Steffen Graf (Germany)

Need to connect your circuit to a PC to transfer measurement values or data? How about wirelessly? If you think that would be way too complex, think again. The solution offered here is a Bluetooth device which from your circuit's point of view looks just like a UART with a PC (or other device) attached to the other end. It's as simple as plugging in a USB to TTL cable but without the wires!



It is often the case that a designer needs to connect a circuit or some equipment to a PC to transfer data or measurement values. One of the simplest methods is to make use of the computer's serial port but fewer and fewer desktops and hardly any mobile PCs are equipped with an RS232 or parallel printer port these days. The favoured port is now via the USB connector but from a hardware designers point of view this is not the simplest solution. There are not too many microcontrollers available with an integrated USB port so additional hardware is the minimum requirement. One solution is to use a specialist USB interface chip which can be driven from a UART in the external controller circuit; it then translates the TTL signal levels to USB data. Alternatively this hardware can be encapsulated into a cable to make a USB to TTL serial cable like the one described in Elektor (by FTDI and available from the Elektor shop as item number 080213-91 [1]). On the PC side this creates a virtual COM port through which the external circuit can be accessed. Now with a terminal emulation program running on the PC, bytes of information from the external microcontroller system can be displayed on the screen and commands can be sent to the external system from the PC keyboard. You may be using the latest computer and the most recent version of Windows but that's just the way it has been done for years!

Who needs cables anyway?

This project describes an alternative method using more up-to-date interface technology. Almost every mobile PC is now supplied with a built-in Bluetooth interface but even if yours is not equipped with one (or you prefer to use a desktop PC) then you can easily buy a Bluetooth stick for a few pounds that plugs into a free USB port and provides the PC with Bluetooth connectivity. The circuit here provides the same connectivity as a USB to TTL cable i.e. all the UART connections are available to connect to the microcontroller in the external circuit. In use it is only necessary to wait for the PC to recognise the Bluetooth module – and it's ready to go! Again on the PC side a terminal emulation program can be used (or some other PC software which can send and receive data from a COM port).

The Bluetooth chip used here is the LMX9838 [2] from National Semiconductor. This SMD device is particularly small (it is thinner than the BTM-222 module used in 'Bluetooth with the ATM18' project described in the December 2009 edition of Elektor). A block diagram of the chip showing the UART interface is given in **Figure 1**. The RF transceiver and Bluetooth stack necessary for the (relatively complex) Bluetooth communication is integrated in the chip. Also included is an EEPROM to store configuration data.
The chip can of course be directly mounted (using hot air only) on the finished circuit PCB but a more flexible solution is to mount it on its own small PCB and bring out the UART connections and power supply to a 6-way connector compatible with the type of connector used for a standard TTL to USB cable. This allows the module to be used in place of the serial cable to give an instant Bluetooth RF communication link.

The PCB

For consistency we have used the same type of connecter and pin assignments as were used in the adapter cable mentioned above. This means that existing Elektor projects such as the battery monitor [3] or the Elektor ATM18 Testboard (see **Figure 2**) can directly use this Bluetooth dongle and connect wire-

lessly to a PC without the need to write a single line of program code!

The small PCB contains the minimum number of external components necessary for the chip. There is a voltage regulator and a quartz crystal (see the circuit diagram in **Figure 3** and the PCB layout in **Figure 4**). The crystal (and its loading capacitors C9 and C10) are not strictly necessary and need only be fitted if you want to make use of the module's low-power mode. Pad 27 (32K+) must be connected to GND if the low power mode is not used. In this case C10 can be replaced by a 0 Ω resistor.

The module is configured using both solder bridges and software. Jumpers JP1 and JP2 allow easy swapping of the RxD and TxD lines to connector K1 without the need to modify the PCB.

A combination of jumpers fitted at JP3 to JP5 defines the serial communication speed. It can be set to either 9600, 115200, 921600 Baud or 'Read from NVS' (see Table). The 'Read from NVS' (Non-Volatile Storage) mode uses the value stored in EEPROM. This value is usually 9600 Baud.

Using the 'Simply Blue Commander' [4] software tool running on a PC allows you to configure the module from a PC via a UART interface (note, only 3.3 V supply allowed!). The baud rate can be set in the range from 2400 to 921600 Baud, other parameters such as parity, stop bits and flow control can also be programmed.

LEDs D1 und D2 indicate the units Bluetooth status; D1 is lit when the unit is not connected to another Bluetooth device and D2 flashes to indicate communication with another Bluetooth device otherwise it remains lit.

Provisions have been made on the PCB layout for the connection of an audio channel to the module. With the addition of an external audio codec this would allow the module to form the basis of a Bluetooth headset.

A bit more background

Communication with a PC is just one of the more basic applications of this Bluetooth dongle. With two modules it is possible to build a wireless link connecting two circuits. There is no doubt that Bluetooth is an increasingly popular interface found

Features

- SPP Protocol fully Integrated 'on chip' (other Bluetooth devices behave as if they are connected via a serial cable)
- No configuration necessary in slave mode, Plug & Play like a USB to TTL cable
- Module can be configured as master via the UART allowing two modules to communicate
- Communication up to 921600 Baud (configurable from 2400 to 921600 Baud using jumpers or software)
- 5 V supply uses an on-board voltage regulator
- Pin compatible with the USB to TTL adapter cable from FTDI
- Direct interface with microcontroller (3.3 V) possible
- UART including handshake signals
- 2 LEDs indicating Bluetooth link status and traffic
- Expansion with an external audio codec possible
- Low power mode using optional 32 kHz crystal

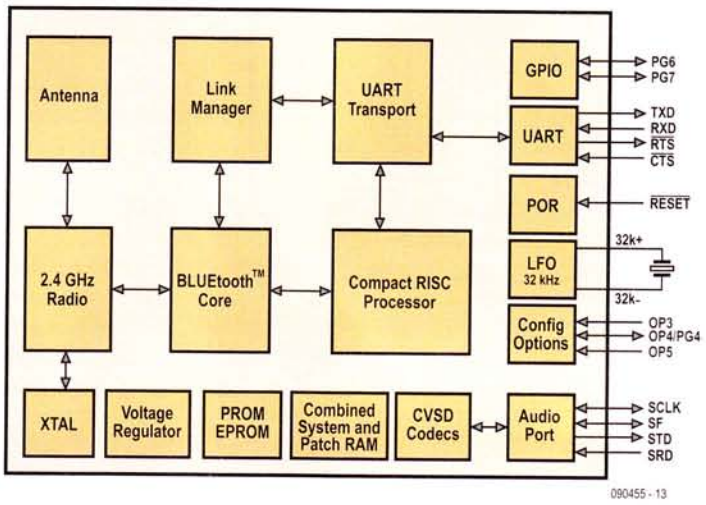


Figure 1. Block diagram of the Bluetooth chip (reproduced from the National Semiconductor data sheet [2]).



Figure 2. The connector used on Existing Elektor projects for connection of the USB to TTL cable from FTDI [1] will also plug into the Bluetooth-Dongle.

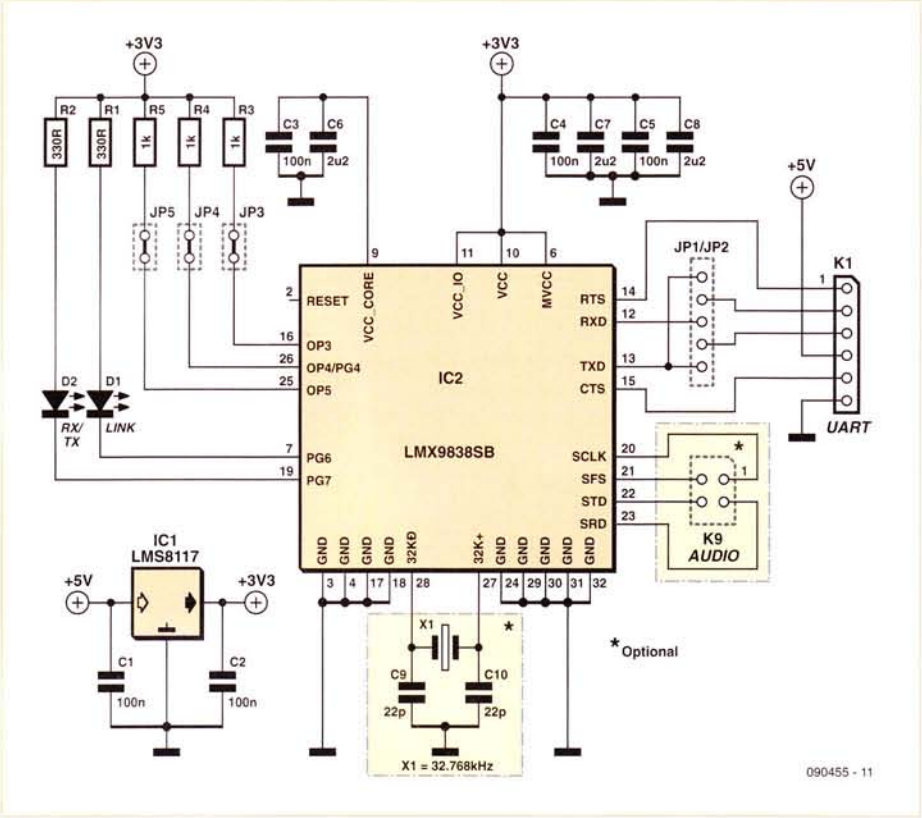


Figure 3. The dongle circuit diagram. Jumpers JP3 to JP5 define the communication baud rate.

Table 1. Baud rate selection

Baudrate	JP3	JP4	JP5
9600	Fitted	Open	Fitted
115200	Fitted	Fitted	Open
921600	Fitted	Fitted	Fitted
Read from NVS	Fitted	Open	Open

COMPONENT LIST

Resistors (all 0805)
R1,R2 = 330Ω (1%)
R3..R5 = 1kΩ (1%)

Capacitors (all 0805):
C1–C5 = 100nF
C6..C8 = 2µF2
C9,C10 = 22pF

Semiconductors
D1 = LED, blue, SMD
D2 = LED, red, SMD
IC1 = LMS8117-AMP3.3
IC2 = LMX9838SB

Miscellaneous
X1 = 32.768kHz quartz crystal (CL = 6pF, 20ppm)

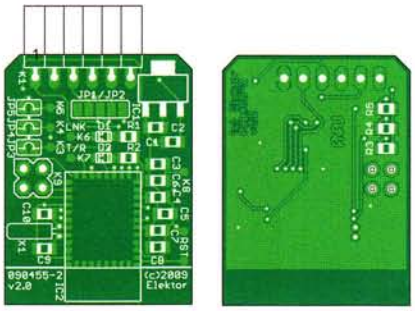


Figure 4. Component placement on the small PCB.

K1 = 6-pin SAL pinheader, 2.54mm pitch, right angled
PCB, see www.elektor.com/090455

on mobile phones, PDAs and other mobile devices and it is necessary to invest some time studying the protocols if you intend to make full use of the communication possibilities. Next we will go on to explore just some of the more basic operations. Detailed information of Bluetooth [5,6] and the chip [2,7] can be found on the Internet.

Much like communications over Ethernet based networks Bluetooth also has many abstract layers to control the exchange of information. In the following description we only refer to the protocols and profiles implemented in the Bluetooth chip, there are a whole lot more described in the Bluetooth specification!

At the lowest physical layer Bluetooth uses radio channels in the 2.4 GHz ISM band to send and receive data. The use of fast frequency hopping reduces the effects of interference and error detection techniques make communication more robust. With this method of communication the stream of data is divided up into individual packets prior to transmission and then reassembled in the receiver in the correct order. This is taken care of by the so-called L2CAP (Logical Link Control and Adaptation Protocol).

At another layer above the software takes care of simultaneous execution of applications and manages connections to other devices. At this level the GAP (Generic Access Profile), establishes links and governs which device has access to which service.

At another level up are the SDAP (Service Discovery Application Profile) and SPP (Serial Port Profile). SDAP detects Bluetooth devices and can determine which protocol the device understands and establishes links. The Serial Port Profile or SPP is of particular interest in our application here, it uses the RF link to produce a virtual serial data cable between two Bluetooth devices with the usual UART signals at either end to control data flow. This serial link is relatively easy to configure and simple to use. The path does have a relatively high latency (in the region of a few milliseconds) but this should not cause too much of a problem in the majority of applications using digital data transfer.

Communication set up

From a user's point of view to establish a Bluetooth link one of the devices assumes a

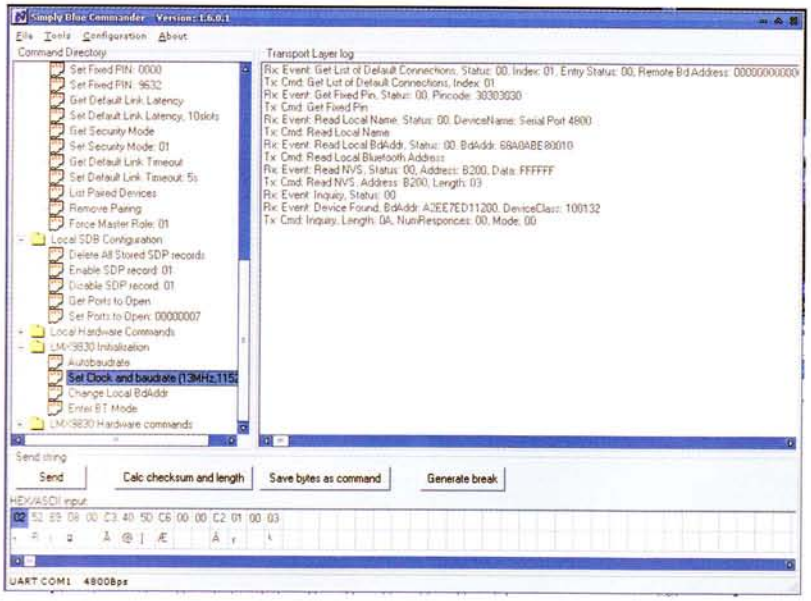


Figure 5. The PC tool 'Simply Blue Commander' allows request generation from its menu.

role as master and issues a 'request' message. For this to occur it is necessary to send the corresponding instruction (in hexadecimal) to the UART in the Bluetooth chip. An interpreter is integrated in the chip.

The other 'slave' device responds by sending a Bluetooth 'confirm'. When this is received by the master device it is converted into the corresponding hex code sequence and sent out from the master's UART.

Request (and confirm) messages always use the following (hexadecimal) format:

Start byte	02
Type ID	1 Byte
Opcode	1 Byte
Data Length	2 Bytes (Low byte first)
Checksum	1 Byte
Data	X Bytes
Stop byte	03

The Type ID can be 52 (Request), 43 (Confirm) or 69 (Indication) which denotes the transfer of additional information.

So the following sequence illustrates a typical communication exchange (opcodes and data bytes are shown in italics):

Devices in range receive inquiry request:
02,52,*00*,03,00,55,*0A,00,00*,03

A typical reply would be for example:
02,43,*00*,01,00,44,*27*,03
02,69,*01*,09,00,73,***B4,EE,7E,D1,12,00***,*10*
,01,32,03

02,43,*00*,01,00,44,*00*,03

The sequence 'B4,EE,7E,D1,12,00' shown in bold is the unique hardware address of the target Bluetooth device. This address is assigned by the device manufacturer much like the MAC address of a network adapter or network interface card.

Now the name of the target device can be requested:
02,52,*02*,06,00,5A,***B4,EE,7E,D1,12,00***,03

A typical reply would be:
02,43,*02*,12,00,57,*00*,***B4,EE,7E,D1,12,00***,
0A,***54,65,73,74,44,65,76,69,63,65***,03
Which contains the Bluetooth address again and then the name of the device (5 4,65,73,74,44,65,76,69,63,65 = the ASCII hex codes for 'TestDevice')

Now using SDAP we can find out all the services available. First we must send an SDAP connection request:
02,52,*32*,06,00,8A,***B4,EE,7E,D1,12,00***,03

If the connection is successful the received reply is: 02,43,*32*,01,00,76,*32*,03

Next all the services can be interrogated or as shown here just the available SPP service:
02,52,*35*,02,00,89,*01,11*
,03

A typical reply:
02,43,*35*,20,00,98,*00,01,*
*02,10,01,11,01,18,****42,6C,7***
5,65,74,6F,6F,74,68,20,53,
65,72,69,61,6C,20,50,6F,7
2,74,20,31,*00*,03
Once again the profile's name is shown in bold:
42,6C,75,65,74,6F,6F,74,
68,20,53,65,72,69,61,6C,20,50,6F,72,7
4,20,31 = Bluetooth Serial Port 1

Now it is established that the device can talk and understand 'SPP' a connection can be configured using SPP connection request:
02,52,*0A*,08,00,64,*01*,***B4,EE,7E,D1,12,0***
0,*01*,03

The correct PIN is now sent (default value '0000'):
02,52,*75*,0B,00,D2,***B4,EE,7E,D1,12,00***,*04*
*,****30,30,30,30***,03
The Bluetooth address is included and also the sequence 30,30,30,30 = 0000 i.e. the PIN

Finally the UART is switched to 'transparent' mode:
02,52,*11*,01,00,64,*01*,03

The Bluetooth chip now stops interpreting the serial data as commands and just passes the data on 1:1.

(090455-I)

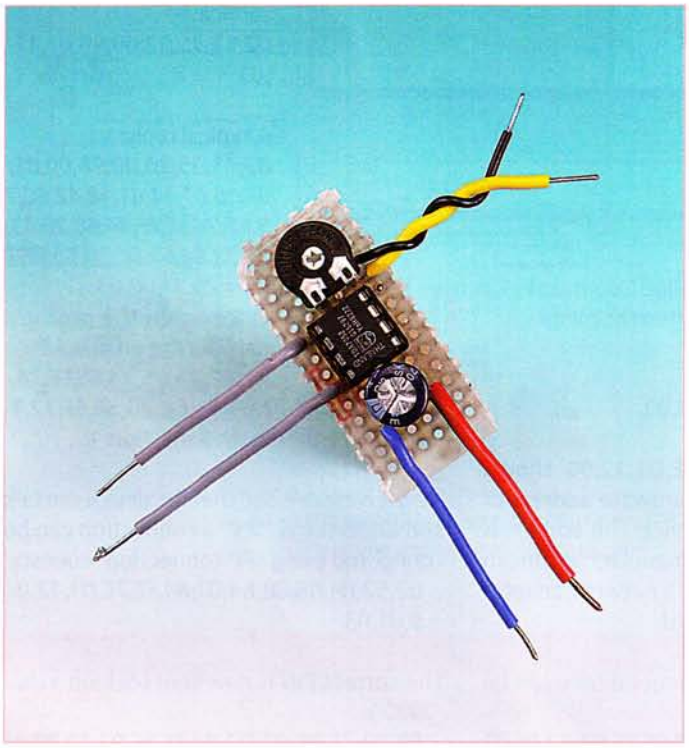
Internet Links

[1] www.elektor.comM/080213
[2] www.national.com/ds/LM/LMX9838.pdf
[3] www.elektor.com/080824
[4] www.national.com/analog/wireless/lmx9838
[5] http://bluetooth.com/Bluetooth/Technology/Works
[6] www.elektor.com/992041
[7] www.national.com/appinfo/cp3000/files/SBK/AN1699_LMX9838SWUG.pdf
[8] www.elektor.come/090455

Audio amplifier in dinner mint format

By Ton Giesberts (Elektor Labs)

There are countless situations and systems devisable in which a sound signal needs to be amplified in order to drive a (small) loudspeaker, but where space constraints rule out the use of a regular



sized amplifier. For these situations, this sub miniature amplifier is perfect. With some skills it can be assembled to a size smaller than an after dinner mint!

The TDA7052, which was released by Philips a many moons ago, is a typical example of a fully integrated circuit. The only external components required are two decoupling capacitors. That's all.
In the circuit diagram of the amplifier you can find an internal schematic of the integrated circuit. It's easy to see two amplifiers connected in a bridge arrangement. This is done in order to squeeze a 'decent' power from the IC at relatively low supply voltages.
A preset has been added to the input to prevent the circuit from being overdriven, this will be appreciated in view of the high sensitivity of the TDA7052. If required, this can of course be a real potentiometer with knob and all to adjust things on the fly.

Maximum power output is just over 1 watt, which is more than enough for most applications. The power supply voltage can be up to 18 V, but be aware that voltages above 6 V or so can cause the IC to become hot. When using higher voltages, use a loudspeaker with an impedance greater than 8 ohms or limit the input signal of the amplifier. Don't worry about FUBR-ing the amplifier though. Even though the IC heats up, an internal thermal security will stop anything from blowing up.

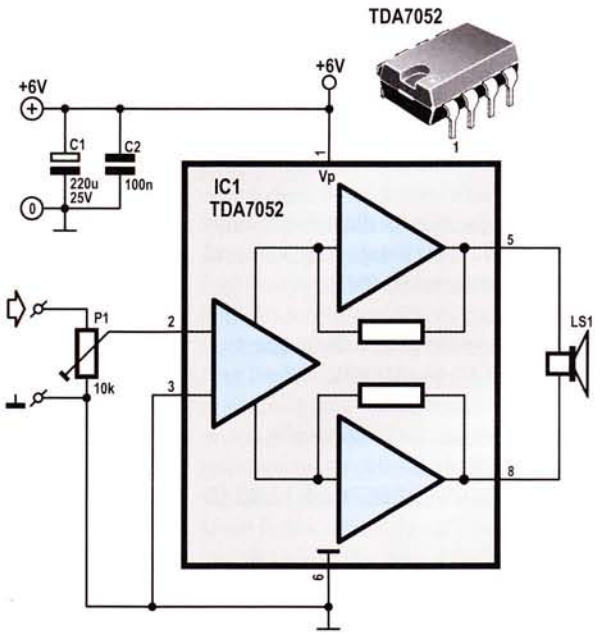
A few measurements were carried out on the prototype and the results in the table below show what happened at a supply voltage of 6 volts and a loudspeaker impedance of 8 ohms:

THD+N*	0.09% (1 kHz, 100 mW in 8 Ω) 0.3% (20 kHz, 100 mW in 8 Ω)
P_{max}	750 mW (THD+N = 1%) 1 W (THD+N = 10%, heavily clipped output signal**)
Gain	38 dB (P1 at maximum)
Supply voltage	3–18 V
Current consumption	5 mA (quiescent) 340 mA (1 W continuous power output)

* THD+N = Total Harmonic Distortion plus Noise
** clipping only noticeable at 2% distortion.

Pretty good results for an amplifier this simple!

The construction of this mini amp is unlikely to cause problems. If you work neatly, the circuit will most definitely work. Some people have taken it as a challenge to make the circuit as small as possible.



Whatever you choose to do, we wish you a lot of fun tinkering!

(i-00909)

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Hexadoku

Puzzle with an electronics touch

Feel like solving a puzzle again? Here's another Hexadoku that hopefully allows you to escape from those daily tribulations for a while. Send the hexadecimal numbers in the grey boxes to us and enter the prize draw for a fine set of Elektor vouchers. Have fun!

The instructions for this puzzle are straightforward. In the diagram composed of 16 × 16 boxes, enter numbers such that **all** hexadecimal numbers 0 through F (that's 0-9 and A-F) occur once only in each row, once in each column and in each of the 4×4 boxes (marked by the thicker black lines). A number of clues are given in the puzzle and these determine the start situation.
All correct entries received for each month's puzzle go into a draw for a main prize and three lesser prizes. All you need to do is send us the numbers in the grey boxes. The puzzle is also available as a **free download** from www.elektor.com.

Solve Hexadoku and win!

Correct solutions received from the entire Elektor readership (all editions worldwide) automatically enter a prize draw for one Elektor Shop voucher worth £ 80 / € 100 and three Elektor Shop vouchers worth £ 40.00 / € 50.00 each.

We believe these prizes should encourage all our readers to participate!

Participate!

Please send your solution (the numbers in the grey boxes) by email to hexadoku@elektor.com – Subject: **hexadoku 02-2010** (please copy exactly). Include with your solution: full name and street address.

Alternatively, by fax or post to: Elektor Hexadoku
1000, Great West Road – Brentford TW8 9HH – United Kingdom.
Fax (+44) 208 2614447.

The closing date is March 2, 2010.

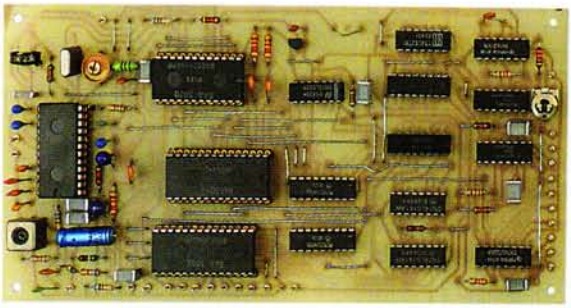
Prize winners

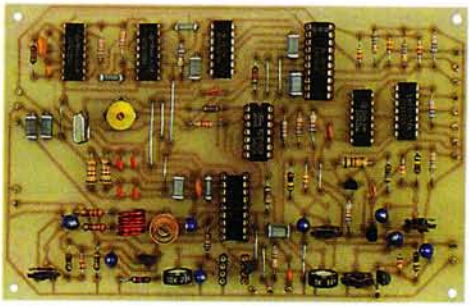
The solution of the December 2009 Hexadoku is: **F1482.**
The E-blocks Starter Kit Professional goes to: Mark Lucas (UK).
An Elektor SHOP voucher goes to: Wolfgang Beckmann (Germany), Keijo Kiirikki (Finland), K. D. Reinartz (Germany).
Congratulations everybody!

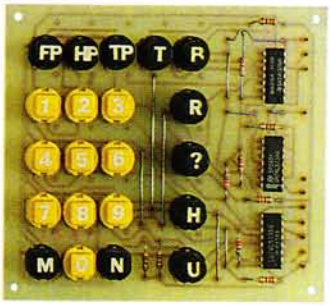
1			C		3					5		7			F
	7	3		C	E	4			1	6	A		5	2	
E			5		F		G	7		2		1			9
		B		1							F		G		
		8											E		
4		9	1	8		E			7		2	G	3		6
	E	D	F	3		C			8		G	4	1	B	
A	6	7			4		F	1		3			9	C	D
8	F	A			7		6	3		9			B	D	C
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C			G		9					F		E			2

1	4	8	9	C	3	D	A	2	E	5	7	B	0	6	F
2	B	D	C	6	5	F	7	9	0	A	8	4	E	3	1
0	6	F	E	9	1	8	2	D	4	B	3	5	C	7	A
5	3	7	A	0	E	4	B	F	6	1	C	D	9	2	8
6	7	2	B	1	D	A	C	8	9	F	4	3	5	0	E
A	5	E	D	4	6	9	0	B	7	3	1	C	F	8	2
C	F	1	4	8	2	3	5	A	D	0	E	7	B	9	6
9	8	3	0	E	B	7	F	C	5	2	6	1	A	4	D
3	A	B	6	F	9	5	D	4	1	C	0	2	8	E	7
F	2	C	7	3	0	E	6	5	8	D	A	9	4	1	B
E	1	9	5	A	8	2	4	3	B	7	F	0	6	D	C
D	0	4	8	B	7	C	1	6	2	E	9	A	3	F	5
4	D	6	1	5	F	B	9	0	C	8	2	E	7	A	3
B	9	5	3	7	A	6	E	1	F	4	D	8	2	C	0
8	E	0	F	2	C	1	3	7	A	9	B	6	D	5	4
7	C	A	2	D	4	0	8	E	3	6	5	F	1	B	9

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Elektor Teletext Decoder (1981)

By Jan Buiting (Elektor UK/US Editorial)

Some of you may be surprised to read this but I don't have to do an awful lot to catch items for presenting on the Retronics page(s) of Elektor — the vintage stuff usually comes to me after a phone call or an email best typified as "lady-of-the-house sez it must go, or else ...". Recently I've also heard these: "Our new management feels the equipment is surplus to their requirements... "; "... me attic's starting to creak" and "... such a pity it goes to waste". To which I say *keep 'm coming* as we have lost most prototypes of Elektor projects published over the past 40 years or so.

Teletext, an information service based on text and simple graphics all carried via analogue TV broadcasts, did take a few years to develop out and mature into a standard (with lots of ifs, buts and hiccups in different countries). It started in 1970 when creative BBC and IBA engineers agreed that the 25 picture lines in the field blanking period of a TV signal were suitable for conveying 'information' instead of just being invisible to viewers at home, as well as mainly black on the oscilloscope They succeeded in filling this vacant area with up to 15 characters per line to convey "internal program information". When in 1972 the BBC's experimental *Teledata* service was launched the capacity had risen to an impressive 32 characters per line. Later that year a conflict of standards occurred when the IBA launched its very own *Oracle* system, to which the BBC responded by renaming its version to *Ceefax* ('see facts'). After two years of polite rivalry and customer frustration up and down the country, the IBA, BBC and BREMA were marshalled by the GPO into agreeing on a standard for teletext, essentially combining the best of *Oracle* and *Ceefax* while adding colour and simple graphics (no fancy stuff — not even Pacman level). Again two years later the 'tests' were ended and the definitive standard laid down. The system was quick to spread across Europe, viewers calling up pages by the 100 K's every day showing weather information, stock exchange lists, airport arrivals/departures and traffic announcements.

Wherever's a dearth there's also an opportunity. I've no evidence of affordable TVs with built-in teletext functionality by around 1980, and the few decoders on the market at the time required major surgery to the TV set. Elektor in 1981 filled the gap by publishing a DIY TT decoder that could be connected between the aerial and the TV set — so no telly in pieces on the carpet!

The Elektor system comprised three circuit boards. The first, described in the October 1981 issue along with a general introduction to the teletext system, contains the decoder using state-of-the-art LSI chips with fine names like VIP (SAA5030), TAC (SAA5041), TIC (SAA5020) and TROM (SAA5051) — thanks for those great acronyms, people at Philips/Signetics! As with most LSI, you kind of glue it all together and follow the datasheet for the most part. I personally remember those SAA50xx ICs were horribly expensive and difficult to get.

The control board described in the November 1981 issue was mostly an interface between the user keyboard and the decoder proper. It contained a bunch of 74LS TTL ICs like shift registers, timers and flip-flops. Rather unexpectedly, the article series seemed to veer off course by suggesting to feed the video output of the decoder to a suitable point in the TV set. Several add-on circuits were shown and hints were given to isolate the TV set from the AC power lines. Fortunately, in December 1981 the original promise of 'no tinkering with the TV set' came true with the description of the video control board. This contained ICs like the LM1889N VHF modulator and the LM1886N RGB decoder, both of which achieved stardom later as they were cheap and an easy way of getting through to the TV screen without opening the family's prize possession. The 'aerial way', finally, came at a great expense in the form of yet another board, this time for the 'teletext receiver', comprising a commercial VHF/UHF TV tuner module and a TDA2541 IF amp/demodulator chip. The obvious missing link to the project, a three-voltage power supply, was published in February 1982.

The complete Teletext decoder was a mammoth project covering about 25 densely filled B&W pages in Elektor and it must have cost a small fortune to construct exactly as detailed in the magazine. The articles had the complete PCB artwork printed at full scale for everyone to etch their single-sided circuit boards at home. Like my friend Eric Post who kindly supplied a fully assembled decoder, neatly assembled, wired and installed in a Teko box (not pictured here).

The ETTD was a fine example of Elektor and its keen readers being ahead of the market, as TV sets with internal teletext were rare and/or expensive at the time. Hence a fully a working teletext decoder was sure to impress friends and neighbours with important information like snow levels on the Chamonix skiing slopes or the zloty exchange rate!

Today, teletext is in the final phase of being killed off by the Internet and digital TV, with many providers folding after about 30 years — starting, ironically, in the UK. It's proof that Latin 'tele' means 'far' in terms of distance, not time.

(090762)

Retronics is a monthly column covering vintage electronics including legendary Elektor designs. Contributions, suggestions and requests are welcomed; please send an email to editor@elektor.com

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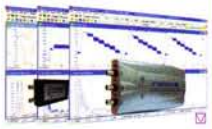
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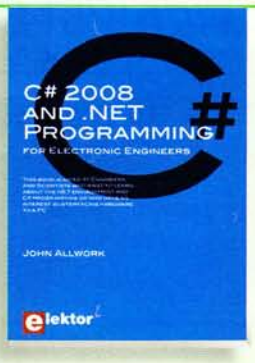


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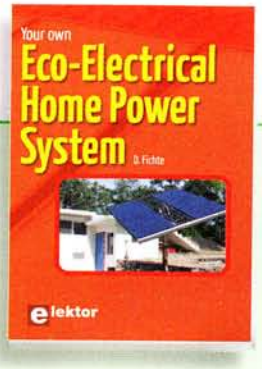


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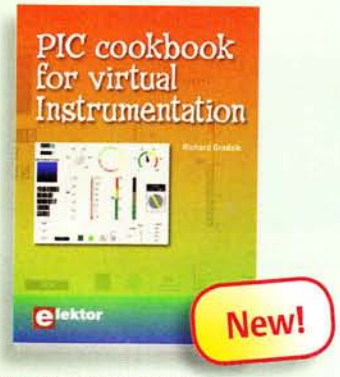


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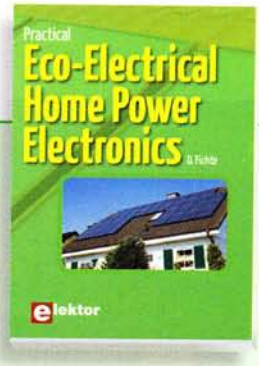


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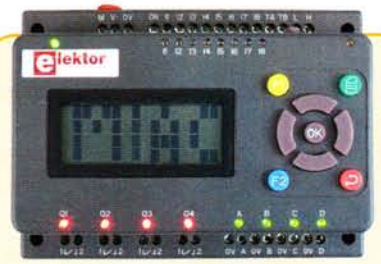


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The program package consists of eight databanks covering ICs, germanium and silicon transistors, FETs, diodes, thyristors, triacs and optocouplers. A further eleven applications cover the calculation of, for example, LED series droppers, zener diode series resistors, voltage regulators and AMVs. A colour band decoder is included for determining resistor and inductor values. ECD 5 gives instant access to data on more than 69,000 components. All databank applications are fully interactive, allowing the user to add, edit and complete component data.

ISBN 978-90-5381-159-7
£24.90 • US $40.20



MIAC for Home Automation

(January 2010)

A MIAC is an industrial programmable logic controller (PLC) that can be used in a wide variety of electronic systems. Internally it has a powerful 18F4455 PIC microcontroller which is connected directly to a USB port. As a result it can be easily programmed using either Flowcode, C or assembly. The article in Elektor's January 2010 issue shows how to implementate a simple home automation system with an alarm by using three MIACs.

Populated PCB in enclosure

Art.# 090278-91 • £154.00 • US $248.40



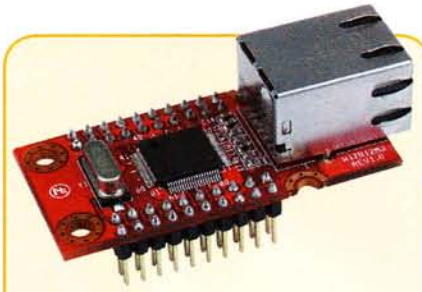
Preselector for Elektor SDR

(December 2009)

Elektor's Software Defined Radio (SDR) is deservedly popular. The performance of a receiver depends to a large extent on its input filters. A selective input circuit improves antenna matching and immunity to interference from other strong signals. This preselector allows the use of up to four filters, tuned under software control using varicap diodes. A tuned loop antenna is also described that lets you use our SDR without an outdoor antenna.

Kit of parts, contains partly populated board, coil formers, ferrite rod with coils

Art.# 090615-71 • £47.00 • US $75.90



R32C Web Server

(November 2009)

The R32C microcontroller goes Internet! A small add-on module for the application board from our September 2009 issue combines a TCP/IP chip plus Ethernet interface, a network connection with built-in transformer and status LEDs. This handy combination makes it child's play to implement a web server and many other Internet applications without getting involved in complexities such as TCP/IP protocols.

PCB, populated and tested WIZ812MJ module with W5100 chip

Art.# 090607-91 • £18.00 • US $29.10



OBD Analyser NG

(September 2009)

The compact OBD2 Analyser in the June 2007 issue was an enormous success – not surprising for an affordable handheld onboard diagnostics device with automatic protocol recognition and error codes explained in plain language. Now enhanced with a graphical display, Cortex M3 processor and an Open Source user interface, the next generation of Elektor's standalone analyser sets new standards for a DIY OBD2 project. The key advantage of this OBD2 Analyser NG is that it's self-contained and can plug into any OBD diagnostic port.

Kit of parts including DXM Module, PCB SMD-prefitted, case, mounting materials and cable

Art.# 090451-71 • £84.00 • US $135.50

Kits & Modules

Product Shortlist

February 2010 (No. 398) £ US $

+ + + Product Shortlist February: See www.elektor.com + + +

January 2010 (No. 397)

USB Magic Eye
090788-1 ..... Printed circuit board ..... 9.90 ..... 16.00
090788-41 ... ATtiny2313-20PU, programmed ..... 9.90 ..... 16.00

MIAC for Home Automation
090278-91 ... Populated PCB in enclosure ..... 154.00 ..... 248.40

Dimmer with a Micro
090315-41 ... PIC12F629A, programmed ..... 7.60 ..... 12.30

December 2009 (No. 396)

Preselector for Elektor SDR
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Top-of-the-Bill Lights Sequencer
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090125-2 ..... PCB, bare (lamp module) ..... 2.30 ..... 3.80
090125-41 ... Controller (PIC18F2550) for main PCB, programmed ..... 14.50 ..... 23.40
090125-42 ... Controller (PIC12F508-I/SN) for lamp unit, programmed ..... 2.30 ..... 3.80

The Vikings Are Coming!
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Minimalistic Time Switch
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November 2009 (No. 395)

Solder Station 'Plus'
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R32C Web Server
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080928-91 ... R32C Starter Kit: processor board populated and tested, Toolchain on CD ..... 27.00 ..... 43.60
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October 2009 (No. 394)

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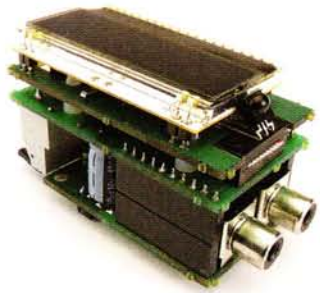
ATM18 VisiOLED

This doorbell has a few features seen in top of the range Miami condos only: visitors have their RFID card scanned at the entrance and the house owner sees a photo of the visitor on an OLED display. A button push opens the door. This ambitious project employs the now famous Elektor ATM18 microcontroller board (from April 2008) and the associated RFID reader (June 2009). The free software is open to extension and expansion!



Three-channel DMX512-A Receiver

The DMX512-A system is used in many of today's lighting systems installed in theatres and concert halls. The same is also increasingly applied for outside lighting of large buildings. In this project a DMX-512 lights control is realised with the aid of a Texas Instruments MSP430 microcontroller. It handles the DMC communication as well as controlling three LED power drivers using pulsewidth communication. A DIP switch allows the DMX address to be set.



Mini Class D Amplifier

Although switching audio power amplifiers are now well established, home constructors often find themselves restricted to simple circuits. The switching audio amp in the March 2010 edition of Elektor is small, neatly designed and comes with a number of extras. The circuit is based around a MAX9744 and outputs 2 x 20 watts at an efficiency of 94%. The project has built-in volume and tone control as well as a backlit LCD. No knobs... everything is adjusted using a remote control!

The March 2010 issue comes on sale on Thursday, February 18, 2010 (UK distribution only). UK mainland subscribers will receive the issue between February 12 and 15, 2010. Article titles and magazine contents subject to change; please check the Magazine tab on www.elektor.com

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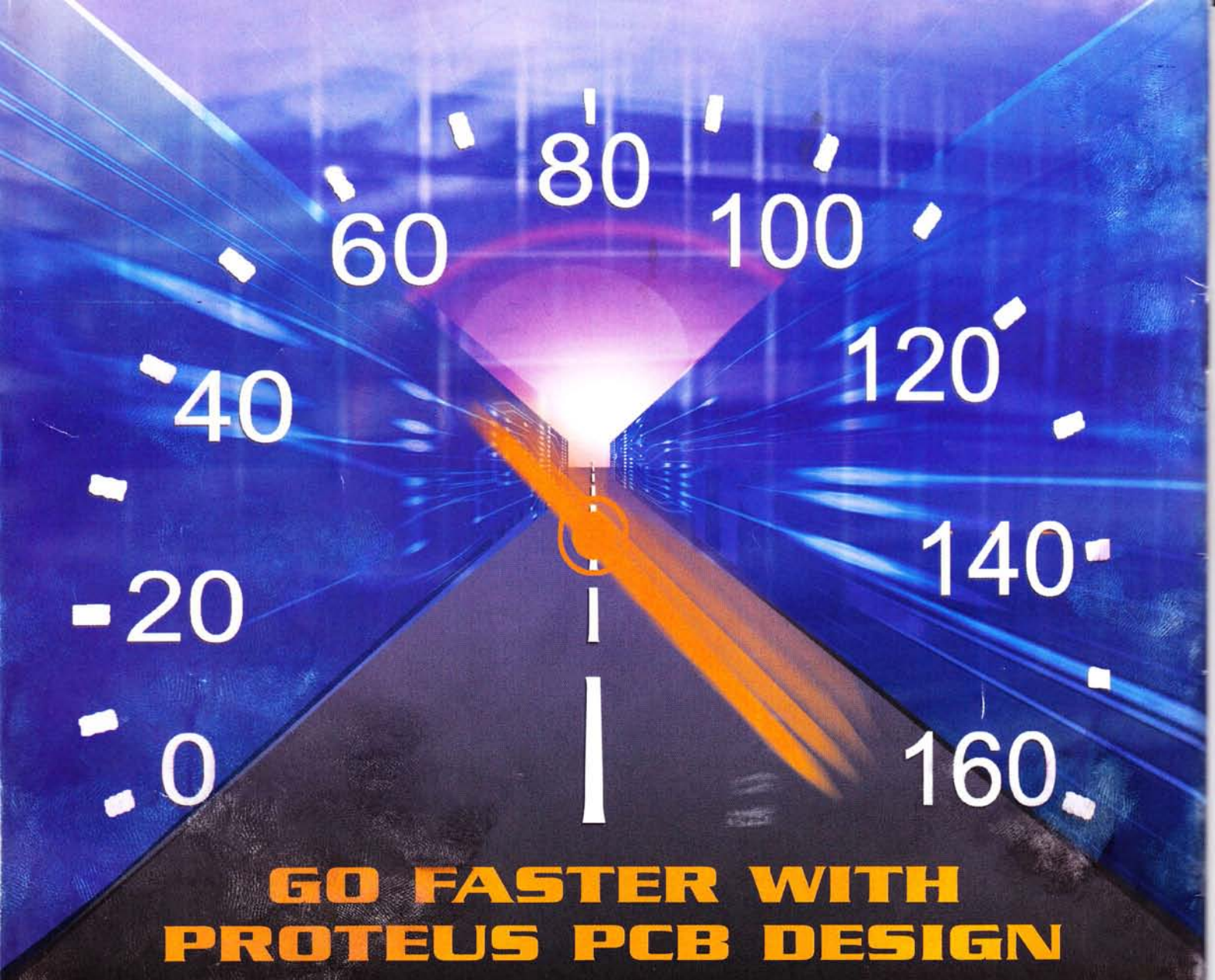
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